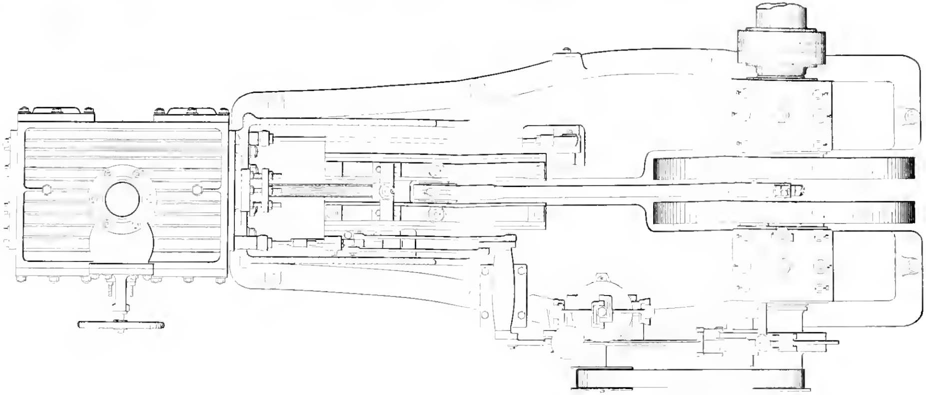
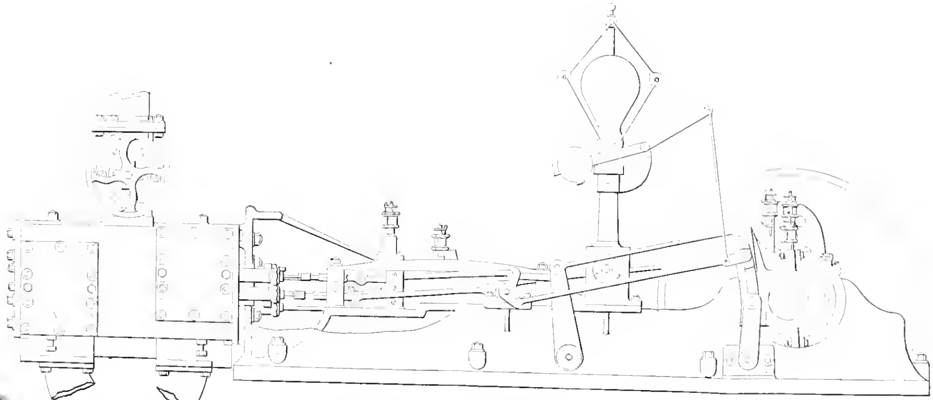
GENERAL VIEW OF ENGINE.



Plan.



Elevation.—Bed shown partly in section.

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THE

JOURNAL

OF THE

FRANKLIN INSTITUTE

DEVOTED TO

SCIENCE AND THE MECHANIC ARTS,

PUBLISHED BY

THE INSTITUTE,

Under the Direction of the Committee on Publication.

Vol. CXIV.—Nos. 679—684.

THIRD SERIES.

VOL. LXXXIV.—JULY TO DECEMBER, 1882.

PHILADELPHIA:
FRANKLIN INSTITUTE, NO. 15 SOUTH SEVENTH STREET.

1882.

JOURNAL OF THE FRANKLIN INSTITUTE.

Vol. CXIV.

INDEX.

JOURNAL

OF THE

FRANKLIN INSTITUTE.

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXIV. JULY, 1882. No. 1.

DESCRIPTION OF THE EDISON STEAM DYNAMO.

By T. A. EDISON, Ph.D., and CHARLES T. PORTER.

[Read at the Philad'a meeting of the Amer. Soc. Mech. Engs., April, 1882.]

The central Edison station of the first district in New York City will, when fully equipped, be supplied with twelve dynamos, each of which is nominally rated as a 1200 light machine, at 16 candle-power incandescence, but is capable of supplying 1400 lights of this power, continuously, and with high economy, without heating the armature, or burning or injuring the commutator or brushes. This increased capacity is due to improvements in the lamp itself.

The armature of each dynamo is driven by a Porter-Allen engine, of $11\frac{3}{16}''$ diameter of cylinder by $16''$ stroke, directly connected, and making 350 revolutions per minute, giving a piston travel of 933 feet per minute.

The steam is supplied by eight Babcock & Wilcox boilers, of 2000 aggregate horse-powers, and which will work under a pressure of about 120 pounds. These occupy the basement of the building. Over them, the first and second floors being removed, an iron superstructure is erected entirely separated from the walls of the building, and on this the combined dynamos and engines are placed.

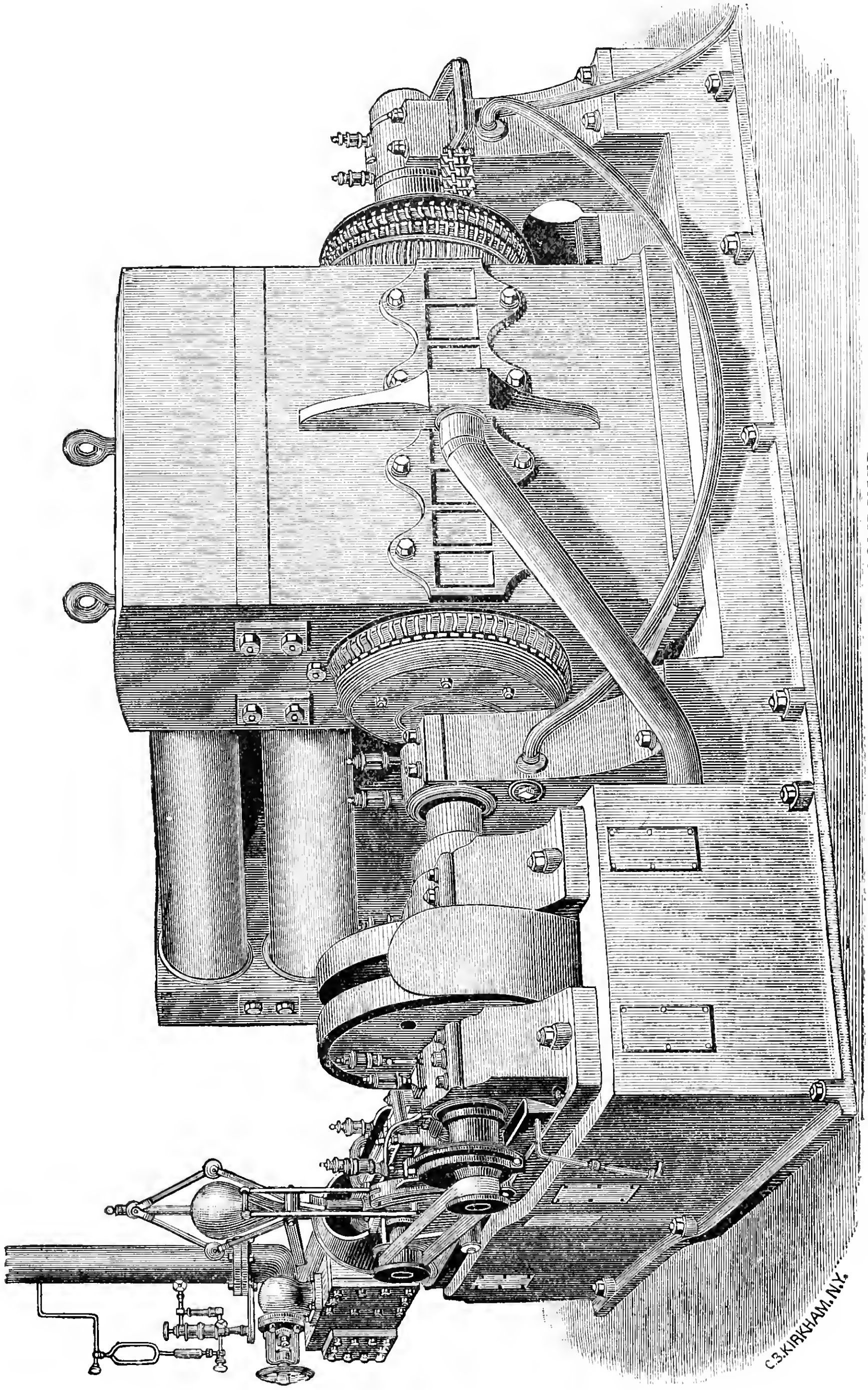


Fig. 4.—DYNAMO AND ENGINE COMBINED.

One-half of this equipment is now nearly ready for service, and the remainder is expected to be completed during the coming season.

The armature of the dynamo is of the form commonly known as the Siemens armature, but in its construction and "connecting up" it differs radically from all others.

The foundation of the armature, or the iron core which is built upon the shaft, is made up of sheet-iron disks, separated from each other by sheets of tissue paper, and bolted together. This has all the advantages of a solid iron core in strengthening the magnetic field, while it completely prevents the great loss of power by local currents, which would circulate in the iron if it were solid. In the place of insulated wires, the cylindrical face of the armature is made up of heavy copper bars, trapezoidal in section, each bar being insulated, and also separated frem its neighbors and from the iron core underneath by an air space.

The connection between the bars on opposite sides of the armature, to form the electrical circuit, is made by copper disks, of the same diameter as the core. At each end of the core are one-half as many of these copper disks as there are bars, each disk being insulated from its neighbors, and the whole being bolted together in such a manner as to form, with the disks of sheet-iron constituting the core, one solid mass. Each disk is formed with projecting lugs on its opposite sides, to which the two bars are connected.

The connections between the opposite surfaces of an armature are of no benefit in generating an electric current, but are a necessary evil, introducing useless resistance into the circuit. By using for this connection copper disks in the manner described, a great weight of copper is disposed in a limited space, and so this useless resistance, and consequent loss of energy, is reduced to a minimum.

This method, moreover, reduces the work to a simple machine construction, in which all the parts are duplicates, and the operations can be much cheapened and facilitated by the use of special tools.

The spaces between the armature bars admit of a free circulation of air, thereby preventing the accumulation of heat, and increasing to an enormous degree the capacity of the machine. The armature is at intervals wound with piano wire over the bars to resist the centrifugal force developed by their revolution.

The commutator and brushes of an electrical machine are the parts subject to the greatest depreciation. In this machine all parts of the

end of the armature are so constructed as to be easy of access, and they can be quickly and cheaply repaired, or removed and replaced by new parts, when necessary. Any accident would require but a short stoppage for repairs.

Provision is made for keeping a continuous and rapid circulation of air over the entire face of the armature.

This armature is 27·8″ in diameter by 61″ long. The commutator adds 18″ to this length, and is itself $12\frac{3}{4}''$ in diameter. The armature shaft is of steel, $7\frac{3}{4}''$ in diameter, having a total length of 10′3″. The journals are $6\frac{1}{2}''$ in diameter by 15″ long, and run in Babbit metal bearings in pillow blocks of the box form, giving the greatest stiffness with minimum of weight.

Provision is made for continuous water circulation underneath the boxes, and for continuous lubrication, with traps to prevent the creeping of the oil along the shaft and reaching the commutator, and drains to receive it as it runs through the bearings and convey it to a drip pan.

The magnet is made up of two immense cast iron "pole pieces," between the semi-cylindrical faces of which the armature revolves, twelve cylindrical soft iron cores attached to these pole pieces, and made magnetic by an electrical current circulated in the wire wound around them, and four soft iron keepers connecting the back ends of the cores. Eight of the cores are attached to the upper pole piece, and four to the lower one.

The width of these "poles" is 49″, and their height $61\frac{1}{2}''$. The length of the twelve soft iron cores is 57″, the diameter of the eight upper ones is 8″, and of the four lower ones 9″.

The four soft iron keepers are each 11″ wide by 9″ in thickness, and the total length of the magnet is 94″.

The magnet is insulated by cast zinc bases 3″ in thickness.

The weight of the dynamo is as follows:

Armature and shaft, . .	9,800 lbs.
Two pillow blocks, . .	1,340 "
Magnet, complete, . .	33,000 "
Zinc bases, . . .	680 "
Total, . . .	44,820 lbs.

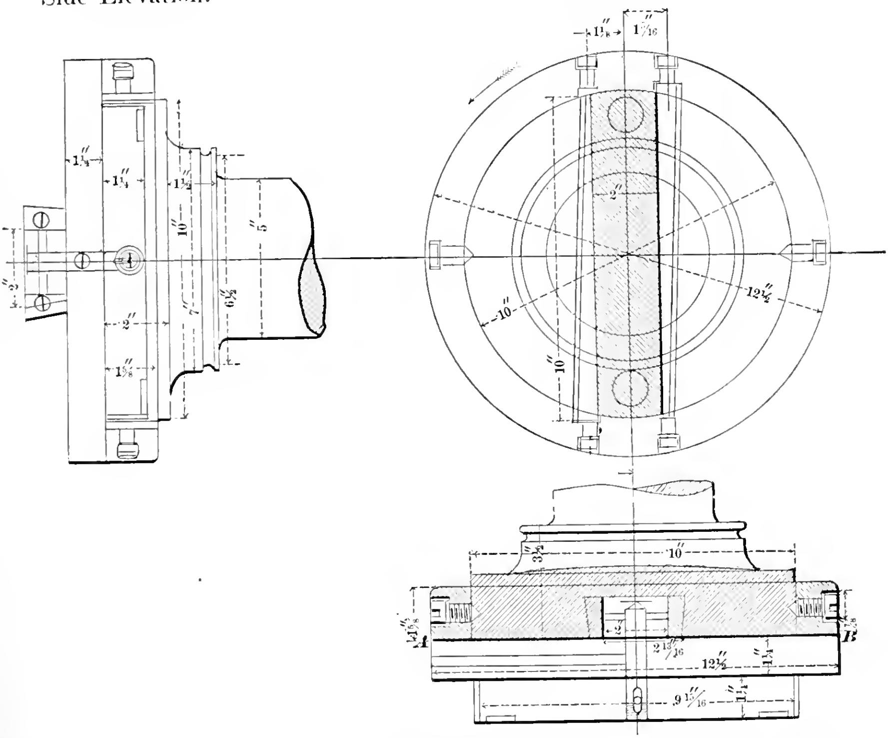
The copper is distributed as follows:

In the armature bars, . .	590 lbs.
" " disks, . .	1,350 "
" magnet wire, . .	1,500 "
Total, . . .	3,440 lbs.

Fig. 1. SELF-ADJUSTING COUPLING.

Side Elevation.

Front Elevation. Tongue in section on the line A B



Plan. Flange on shaft, ring and wedges in section.

Mr. Edison was early impressed with the conviction that to give steady and reliable motion to these armatures it would be necessary to connect an engine to each one of them directly. This combination has been termed by him the Steam Dynamo.

In adapting the Porter-Allen engine to this service, a special construction in some respects was found to be called for. These special features will be briefly described.

It seemed important to avoid a rigid connection between the engine and the armature shafts, which would require the entire series of bearings to be maintained absolutely in line. In place of this, therefore, a self-adjusting coupling has been introduced, of the form shown in Fig. 1, and illustrated by a working model, which will permit of considerable errors of alignment without any abnormal friction being produced in the bearings.

The point of difficulty was the backlash, the engine having no fly-wheel, except the heavy armature itself, which was to be driven through the coupling. Provision was made for taking this up by steel keys of a somewhat peculiar form, between which the tongues of the coupling move freely, while they themselves are immovable. These keys are held between set-screws threaded in wrought iron rings covering the flanges on the ends of the shaft. All the faces liable to move upon each other are oiled from a central reservoir. This coupling is a very compact affair, without a projection anywhere above its surface, and gives every promise of completely answering its purpose.

The engine is made with a forked bed and two shaft bearings and a double crank, and so is completely self-contained. It is shown in plan and elevation in Plate 1.

The shaft having no support beyond these bearings on either side, unusual stiffness was required in the crank-pin to prevent deflection under the great strains to which it is subjected.

A novel form of pin (see Fig 2) was proposed by Mr. Richards, which is found to possess all the rigidity required. It is provided with flanges which are let into each crank, and held each by four screws, as shown, while the shanks of the pin are also forced firmly into the cranks.

Special appliances enabled the work of putting the cranks together in this manner to be done with extreme and uniform accuracy.

The engine is so arranged as to have the valve gear on the side furthest from the dynamo. The engineer has not to go between the engine and dynamo, when running, for any purpose.

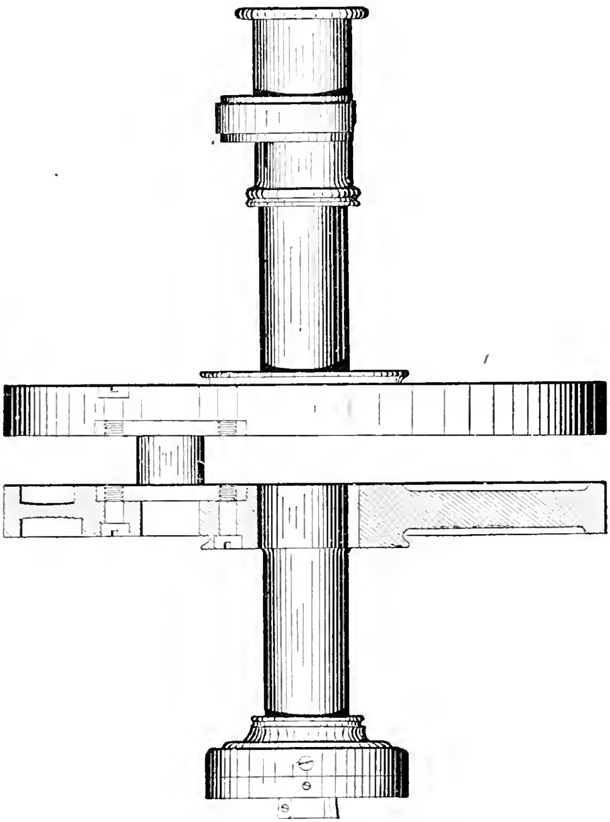
The connecting-rod (Fig. 3), is of steel, and the crank-pin boxes are formed directly in the end of it.

This end is finished from a solid forging, and chambered out for Babbit metal. The bolts are then fitted, after which it is parted and holes are drilled for holding the Babbit securely.

In the connecting-rods for single crank engines of this type per-

manent length of rod is secured by forming the crank pin end solid, and taking up the wear by a wedge closing up the inside box. In these double crank engines this construction is impracticable, but the same object is attained by forming the crosshead end in the manner shown, in which the strap is made permanent and the inside box is closed up by a key bearing against a steel plate.

Fig. 2.—CRANK.



The weight of the reciprocating parts of this engine is as follows:

Piston, with rod, . . .	83 lbs.
Crosshead, . . .	42 "
Connecting-rod, . . .	109 ".
Total, . . .	234 lbs.

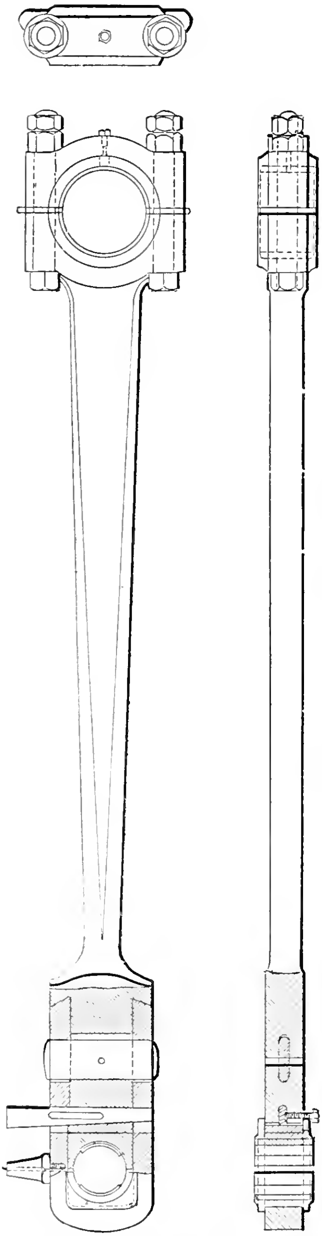


Fig. 3—CONNECTING ROD.

The initial acceleration of this mass, or the force required, on the dead centres, to give it the motion necessary to relieve the crank from strain, is as follows:

$$350^2 \times {\cdot}66 \times {\cdot}000341 = 27{\cdot}57,$$

or 27·57 times the weight of the mass, which gives

$$234 \times 27{\cdot}57 = 6451 \text{ lbs.}$$

The formula is $R^2\, l\, c$, when

R = the revolutions per minute;

l = the length of the crank in decimals of a foot; and

c = the coefficient of centrifugal force.

The connecting-rod is 48″, or 6 cranks, in length. This affects the initial acceleration, making this to be on the dead centre farthest from the crank 7526 lbs., and on the dead centre nearest to the crank 5376 lbs., a difference of 40 per cent.

The area of the cylinder is 98·2 square inches.

The area of the piston rod, $1\frac{3}{4}$ inches diameter, is 2·4 square inches, leaving area of cylinder at crank end 95·8 square inches.

The initial accelerating forces are therefore as follows, viz.: at the end of the cylinder farthest from the crank 77 lbs., and at the end of the cylinder nearest to the crank 56 lbs., on the square inch of piston area.

The counterweight was after some trials fixed at 135 lbs. This leaves 99 lbs. of the reciprocating parts running unbalanced. It is found that this is not sufficient to disturb the stability of the engine, while on the other hand the counterweight

is not so great as to exert an objectionable strain in the vertical direction.

The total weight of the engine is 6445 lbs.

The engine and dynamo are mounted on a cast-iron base plate, made for convenience in two parts, and bolted together.

The dimensions of this base plate are as follows: length 14 feet, width 8 feet 9 inches; and its weight is 10,300 lbs. The entire weight is therefore as follows:

Base plate, . . .	10,300 lbs.
Dynamo, . . .	44,800 "
Engine, . . .	6,450 "
Total, . . .	61,550 lbs.

Fig. 4 is a perspective view of the Dynamo and Engine combined.

The last and most careful test of one of these dynamos gives the following results, as shown by the indicator diagrams, which are here reproduced full size; scale 80 lbs. to the inch.*

The lamps used in all the trials were of the older construction, of which $8\frac{1}{2}$ lamps, at 16 candle power incandescence, require one horse-power of electrical energy.

Since these were placed for experimental uses, improvements in the lamp have increased their economy, so that one horse-power is sufficient to maintain fully 10 of the present lamps at 16 candle power incandescence.

Diagram No. 1 shows the friction of engine and dynamo at 350 revolutions per minute, requiring . . . 13·63 HP

Diagram No. 2 shows the resistance with the magnet circuit on = ... 19·17 HP

Field 5·78 ohms, 103 volts.

*As many persons might doubt about these diagrams having been really taken from any engine and by any indicator at this speed, we have examined the originals taken by a Tabor indicator, and can vouch for their accuracy.—Ed. J. F. I.

The increased resistance due to the magnets was . 5·54 HP

Of this, the calculated energy developed in the magnets

was $\dfrac{103^2 \times 44{\cdot}3}{5{\cdot}78 \times 33{,}000} =$ . . . 2·46 HP

Leaving energy to be accounted for by local currents in iron core of armature, and in armature bars, . 3·08 HP

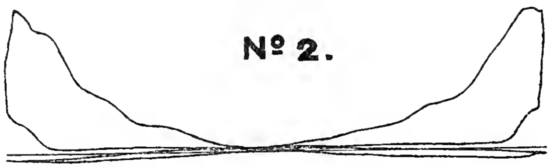
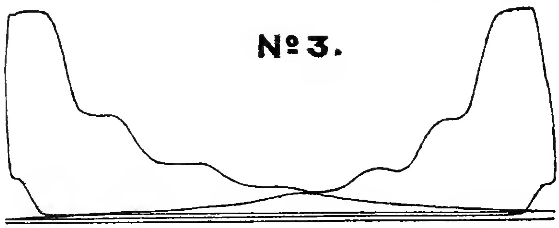


Diagram No. 3 shows the work done in maintaining 300 lamps.



These, in the ratio of $8\frac{1}{2}$ to 10, were equal to 353 lamps of the present construction. The pressure was maintained also at 102 volts, representing 25 candle power, in place of 98 volts, representing 16 candle power incandescence, which requires the number of lamps to be increased in the ratio of 102^2 to 98^2, or to 382 lamps.

The pressure at the armature was 104 volts, showing a loss in the conductor of 2 volts, which would increase the number of lamps as 104 : 102.*

The total correction is therefore as follows:

$$300 \times \frac{10}{8{\cdot}5} \times \frac{102^2}{98^2} \times \frac{104}{102} = 389 \text{ lamps.}$$

The power exerted was . . . 60·6 HP

which gives to the indicated horse-power

$$389 \div 60{\cdot}6 = 6{\cdot}42 \text{ lamps.}$$

---

*The conductors were insufficient, occasioning a loss, that increased with the increase in the number of lamps.

The magnet circuit had now a resistance of 5·28 ohms with 104 volts pressure, representing

$$\frac{104^2 \times 44\cdot3}{5\cdot28 \times 33{,}000} = \quad . \quad 2\cdot75 \text{ HP}$$

Substituting this in place of 2·46 HP in the first trial, we have 19·46 HP, which, deducted from 60·6 HP, leaves net 41·14 HP.

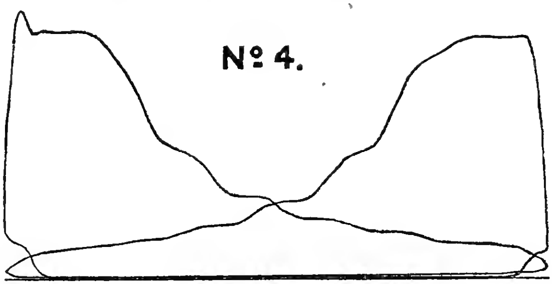
This gives 389 ÷ 41·14 = 9·45 lamps per HP.

Diagram No. 4 shows the work done in maintaining 700 lamps.

The pressure at the lamps was maintained, as in the preceding trial, at 102 volts, which required at the armature a pressure of 105 volts.

The total correction in this case is therefore

$$700 \times \frac{10}{8\cdot5} \times \frac{102^2}{98^2} \times \frac{105}{102} = 919 \text{ lamps.}$$



The power exerted was . . . 115·83 HP

giving to the indicated horse-power,

$$919 \div 115\cdot83 = 7\cdot93 \text{ lamps.}$$

The resistance of the magnet circuit was now 4·78 ohms, with 105 volts pressure, representing, $\dfrac{105^2 \times 44\cdot3}{4\cdot78 \times 33{,}000} = 3\cdot1$ HP.

Substituting this in place of 2·46 HP in the first trial, we have 19·81, which, deducted from 115·83 HP, leaves net 96·02 HP.

This gives 919 ÷ 96·02 = 9·57 lamps per HP.

Diagram No. 5 shows the work done in maintaining 1050 lamps.

The pressure at the lamps was maintained in this trial at only 99 volts, but this required at the armature a pressure of 108 volts, showing a loss of 9 volts in conduction.

The total correction in this case is thus

$$1050 \times \frac{10}{8\cdot5} \times \frac{99^2}{98^2} \times \frac{108}{99} = 1375 \text{ lamps.}$$

The power was . . . . 168·4 HP
giving to the indicated horse-power

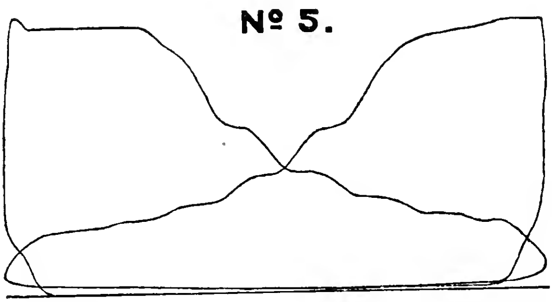
$$1375 \div 168{\cdot}4 = 8{\cdot}16 \text{ lamps.}$$

The resistance of the magnet circuit was now 3·28 ohms, with 108 volts pressure, representing

$$\frac{108^2 \times 44{\cdot}3}{3{\cdot}28 \times 33{,}000} = 4{\cdot}77 \text{ HP.}$$

Substituting this in place of 2·45 HP in the first trial, we have 21·48 HP, which, deducted from 168·4 HP, leaves net 146·92 HP.

This gives $1375 \div 146{\cdot}92 = 9{\cdot}36$ lamps per HP.



It will be seen that the losses of efficiency due to undiscovered resistances are only

In the first case, . 10 — 9·45 = ·55 HP per lamp,
In the second case, . . 10 — 9·57 = ·43 HP per lamp, and
In the third place, . 10 — 9·36 = ·64 HP per lamp,

Averaging 5·4 per cent.

The friction in the journals of the armature, when driven in this manner, does not increase with the resistance, and, on account of the action of the reciprocating parts of the engine, that in its bearings is also nearly a constant quantity, whatever the load may be.

The above figures show this very clearly, the subtraction of the friction diagram in each case exhibiting substantially the same net power per lamp.

ON THE EFFICIENCIES OF THE STEAM BOILER AND ON THE CONDITIONS OF MAXIMUM ECONOMY.

By Robert H. Thurston.

[Presented to the American Society of Mechanical Engineers, Philadelphia Meeting, April, 1882.]

In the design and construction of a steam boiler, and in its operation, problems arise which must be solved, by the mechanical engineer, in their natural order before he can say with confidence that the best interests of the purchaser or proprietor of the apparatus are fully met in its construction and management. Such problems form the subject of this paper.

(*1.*) *The "Efficiency of the Steam Boiler"* is the ratio of the total quantity of heat utilized in the production of steam to that set free in the combustion of the fuel. It has as the maximum limit unity. It is a function of area of heating surface and quantity of fuel burned, and of factors dependent upon the character of the fuel and of its combustion, and upon the design of the boiler.

(*2.*) *The "Commercial Efficiency"* or the *"Efficiency of Capital"* employed in the maintenance of steam-generating apparatus of a given power is measured by the ratio of quantity of steam produced to the cost of its continuous production, *i. e.*, by the reciprocal of the total cost of steam per pound or per cubic foot at the required pressure. This efficiency is a maximum when that cost is a minimum.

(*3.*) *The Efficiency of a Given Boiler Plant,"* as the writer would call it, or the commercial efficiency of a steam boiler already in place and in operation, is still another quantity. It is a maximum when the work done by the boiler can be increased beyond that for which it was proportioned—if designed originally to give maximum efficiency of capital at a pre-arranged power, as above—until the amount of steam made by that boiler per dollar of working expense is made a maximum.

These three efficiencies differ essentially in their character, and are determined by different processes. In the first case, the engineer designing a boiler finds himself called upon to determine what is the maximum efficiency that it will be economical, or otherwise advisable,

to endeavor to secure, and then calculates the proportions necessary to secure that efficiency. Or, knowing the proportions of any boiler already designed and built, he may be required to calculate its probable efficiency and the quantity of fuel called for to make a certain quantity of steam, *i. e.*, to determine the steam generated per pound of coal burned.

In the second case, the designing engineer calculates the proportions of heating surface to grate surface or to fuel burned, where the quantity of steam required is known, and the conditions determining costs, which shall give that quantity of steam at least total running expense.

In the third case, the boiler is in place and in operation, and it is found that it is advisable to ascertain what quantity of steam can be made when its cost per unit of weight or of volume is a minimum.

In the first two cases, the variable element is usually the area of heating surface per pound of fuel burned in the unit of time; in the last, the variable is the quantity of fuel burned or of steam made.

(*4.*) *To What Capacity may any Given Boiler be Forced without Exceeding that Cost of Steam at which a Paying Profit is Given?* is another problem in steam boiler efficiency and one which is of more frequent occurrence, and is usually more important than the preceding.

The economical maximum of steam production is evidently determined by the money value, to the producer, of the steam made.

(*1.*) *Efficiency of the Steam Boiler.*

This case has been studied by Rankine, who deduces a very simple and handy formula for the efficiency of a boiler of known proportions, using a fuel of known calorific value.

Taking the rate of conduction of heating surfaces as varying as the square of the difference of temperatures of the gas and of the water on opposite sides of the sheet, the formula

$$E = \frac{1}{1 + \frac{ac'^2 W^2}{SH}}$$

is readily deduced, in which E is the efficiency, a a constant, c' the specific heat of the furnace gases, and W their weight; while H is the total heat expended and S the heating surface. This expression is further transformed into

$$E_1 = \frac{BE}{1 + \frac{AF}{S}}$$

in which E is the theoretical evaporative power of the fuel per pound, E_1 the probable actual evaporation in a boiler in which F is the weight of fuel burned on the unit of area of grate, and S is the area of heating surface per unit of the same area.

A and B are here coefficients, having values respectively of 0·3 to 0·5 and 0·9 to 1 for bituminous coals, according to Rankine, and from 0·3 to 0·5 and from 0·8 to 0·9 with anthracite coal, as determined by experiments made by the writer. The lower values of A are obtained when using a minimum air-supply and the value of that coefficient is seen, by comparing the two equations just given, to vary as the square of the quantity of air supplied to the fuel. The value of B is dependent upon the character of the boiler, being greater as the design and construction are improved.

The following are illustrations of the results thus obtained:

EFFICIENCY OF STEAM BOILERS.

$\frac{F}{S}$	I. $A = 0·5$ $B = 1$	II. $A = 0·3$ $B = 1$	III. $A = 0·5$ $B = 1$	IV. $A = 0·3$ $B = 1$
0·17	0·92	0·95	0·83	0·86
0·33	0·87	0·91	0·78	0·82
0·40	0·83	0·89	0·75	0·80
0·50	0·80	0·87	0·72	0·78
0·67	0·75	0·83	0·68	0·75

EXPENSES OF OPERATION.

The expenses of operating a steam boiler may be classed under three heads:

(1.) Those costs of boiler and its maintenance which are dependent upon the size and the character of the boiler itself and its attachments, such as interest on cost of boiler and setting, rent of building and other items on construction account, such as taxes, insurance, repairs and depreciation, etc., etc.

(2.) Those costs of operation which are dependent upon the quantity of steam made and of fuel consumed, such as market price of fuel, cost of transportation, storage (an important item on shipboard especially), and of feeding into the furnace, cost of feed-water and its introduction into the boiler, and a certain part of other costs of attendance and supply.

(3.) In addition to these variable expenses are often, perhaps usually, to be counted certain constant expenses which are unaffected by any change of proportions of boiler likely to be made in the assumed case, such as nearly, or quite frequently all, the costs of attendance.

(2.) *Commercial Efficiency of the Boiler.*

A given amount of steam being demanded, it may be obtained from a small boiler using fuel extravagantly or from a large boiler using fuel economically. In each case arising in practice, there will be found a certain easily determined proportion of heating surface to grate surface and a definite size of boiler which will, on the whole, supply the desired quantity of steam most economically. Thus:

Let the total cost of fuel per annum and per pound burned per hour on the square foot of grate or on the square metre be called C. Let the total cost per annum of boiler, per square foot or per square metre of heating surface, be called D, and let $\frac{C}{D} = R$. In the first item is included all items of Class 1, and in the second all of Class 2.

Then the cost of boiler maintenance per annum is DSG, where S is the area of heating surface per unit of area of grate and G is the area of grate. The cost of fuel, etc., per annum, as per Class 2, is CFG, if F is the weight of fuel burned per unit of area of grate.

The total of costs variable with change of proportion of boiler is

$$P = DGS + CFG.$$

The profitable work of the boiler is measured by the quantity, by weight, of steam made, $FGE_1 = W$; E_1 being the evaporation of water per unit of weight of fuel.

The ratio of cost to work done is

$$y = \frac{P}{W} = \frac{DGS + CFG}{FGE_1} = \frac{CF + DS}{E_1F}.$$

This quantity being made a minimum by variation of the area S, the most economical boiler is obtained.

But E_1 is a function of S and, taking the value of E_1 from the equation

$$E_1 = \frac{BE}{1 + \frac{AF}{S}},$$

we obtain

$$y = \frac{(DGS + CFG)\left(1 + \frac{AF}{S}\right)}{BEFG} = \frac{DGS + ADFG + CFG + \frac{ACF^2G}{S}}{BEFG}$$

$$= \frac{DS + ADF + CF + \frac{ACF^2}{S}}{BEF}$$

which is a minimum when

$$S = F\sqrt{\frac{AC}{D}} = F\sqrt{AR}; \quad \frac{S}{F} = \sqrt{AR}.$$

In illustration: Let a boiler, set in place, complete with all its appurtenances and in running order, cost \$3 per square foot of heating surface, and the annual charges on all accounts entered in Class 1, above, be 20 per cent. on this cost, the annual charge becomes $DS = \$0.60 \times S$ per square foot of grate, *i. e.*, $D = \$0.60$. Let the cost of operation, as for Class 2, amount to \$15 per annum per pound of fuel burned per hour on the square foot of grate; then $CF = \$15$; $C = \$15$; $\frac{C}{D} = R = 25$.

Assume $F = 10$ pounds of fuel per hour per square foot of grate, $A = 0{\cdot}5$.

For this case, then, the boiler should have per square foot of grate

$$S = F\sqrt{AR} = 10 \times (0{\cdot}5 \times 25)^{\frac{1}{2}} = 35;$$

35 square feet of heating surface.

Similarly we get the following values:

COMMERCIAL EFFICIENCY OF BOILERS.

Ratio of Areas of Heating and Grate Surfaces.

Values of S.

F / R	6	10	12	15	20	30	40	50
25	21	35	42	52	70	105	140	175
16	17	28	34	42	56	84	112	140
9	12	21	24	32	42	63	84	105
4	8	14	16	21	28	42	56	70

These values are 20 or 25 per cent. lower for forced draught.

Where the boiler is worked almost continuously, as in flour mills and some other establishments kept in operation night and day throughout the year, the higher values will be found correct; when the boiler is worked discontinuously or, as in steam fire engines and some classes of steam vessels, a comparatively small proportion of the annual working time of the establishment or whole plant, the values of S become very small.

It is seen that the best area of heating surface will vary nearly as the square root of the total working time per annum. Boilers worked continuously, worked twelve hours out of the twenty-four, or eight hours in the day, will require, respectively, values of S having the proportion 1, 0·7 and 0·6 nearly.

The total required area of grate is $\frac{W}{E_1 F} = G$; the total area of heating surface is $\frac{WS}{FE_1} = SG = \frac{W(S+AF)}{BEF}$.

The following are examples, in greater detail, of the application of the above:

Expense on Boiler Account and Maximum Commercial Efficiency.

Cases.	*Stationary.* I.	II.	*Marine.* III.	IV.
Class 1 (D).	Cornish.	Tubular.	Tubular.	Tubular.
Total annual cost of boiler per unit of S,	\$1.50	\$2.00	\$3.00	\$2.00
Interest,	.09	.12	.15	.12
Repairs and depreciation,	.15	.20	.45	.30
Rent, insurance and miscellaneous,	.10	.07	1.00	.20
Total value of D,	.34	.38	1.60	.62
Class 2 (C).				
Fuel (@ \$5 for I, II, IV; \$4 for III) per unit of F,	7.50	7.20	12.00	2.00
Transportation and storage,	1.00	1 00	10.00	1.00
Attendance (variable cost),	0.00	0.50	0.50	0.00
Total,	8.50	9.00	22.50	3.00

Value of $\frac{C}{D} = R$,	25	23	14	5
Value of A,	0.5	0.3	0.3	0.5
Value of $\sqrt{AR}$	3.5	2.7	2.0	1.6
Value of F,	8	10	16	20
Value of $\sqrt{AR} = S$,	28	27	32	32

R varies in magnitude very greatly in practice, falling as low as 4 and rising as high as 50 with varying cost of fuel and length of working time.

The engineer thus solves the most important problem in boiler-design which may be thus enunciated: To determine the commercial efficiency of a steam boiler doing a fixed amount of work; or, given all variable expenses of boiler installation, maintenance and operation, to determine what proportion of heating surface to grate surface or fuel burned will give the required amount of power at least total cost.

(3.) *Commercial Efficiency of a Given Boiler.*

A second commercial problem may sometimes be presented to the engineer: A steam boiler is in place and in operation; all constant expenses are known and all variable costs of maintenance and operation are determinable. The question arises, or may arise whenever additional steam is called for: How much can be obtained from the apparatus when driven to such an extent as to yield most steam per dollar of total cost of operation? The independent variable is now the quantity of fuel burned in the boiler, and this is, in the established equation, represented by F, the fuel burned per unit of area of grate. This problem is thus stated:

Given: All expenses, constant and variable, and the method of variation of the latter and the proportions of the boiler as actually constructed, to determine that rate of combustion which will make the Commercial Efficiency of the Given Plant a maximum.

For this case, let K represent that total annual expense of working which is independent of Classes (1) and (2) and which falls into Class (3) and let $k = \frac{K}{G}$.

Let all other symbols stand as before.

Then the total cost of maintenance and operation will be

$$P' = kG + DGS + CFG,$$

while the work done will be, as before,

$$W = FGE_1.$$

The quantity to be made a minimum is, for the present case, the quotient of P' by W,

$$y = \frac{P'}{W} = \frac{k + DS + CF}{E_1 F},$$

F being taken as the independent variable.

This becomes a minimum when we substitute for E_1 its value $E_1 = \dfrac{BE}{1 + \dfrac{AF}{S}}$ and make the first derivative equal zero.

Then we find

$$F_1 = \sqrt{\frac{kS + DS^2}{AC}}$$

When, in this expression for the value of F, giving maximum weight of steam for the dollar expended, we make $k = 0$, the expression may be reduced, as obviously should be possible, to the form shown already to be that giving the solution of the first problem:

$$S = F_1 \sqrt{AR}.$$

The following cases illustrate this problem:

EXPENSES OF BOILER AND MAXIMUM ECONOMY OF PLANT.

Cases.	*Stationary.*		*Marine.*	
	I.	II.	III.	IV.
Cost of maintenance: D,	\$0.34	\$0.58	\$0.88	\$0.62
Cost of operation: C,	8·20	9.00	14.50	3.00
Cost of operation: K,	30.00	25.00	10.50	10.00
For maximum fuel and work: F_1,	16	13	17	21
For maximum efficiency, as before: F,	8	10	16	20

Case No. 1 is that of a Cornish boiler, No. 2 that of a multitubular stationary boiler, No. 3 that of a sea-going steamer and No. 4 that of a yacht.

It is seen that in all cases the weight of steam delivered from the boiler and the quantity of fuel burned at maximum commercial efficiency, for the case assumed, are less than where the boiler—once set and still capable of being forced to deliver more steam than originally

proposed and calculated upon—is worked up to a maximum delivery per dollar of total expense.

"Maximum Commercial Efficiency of Boiler" and "Maximum Efficiency of a Given Plant" are therefore by no means identical conditions, and it will usually be found that when this maximum work can be put on the boiler, it might be done still more economically by a boiler specially designed, as in the first problem, to do the increased quantity of work; the conclusions from this fact being simply that economy dictates that as much steam power as possible should be grouped into a single plant in order to diminish the proportional cost of the constant part of running expenses, *i. e.*, otherwise stated, there being given a certain necessary expenditure, invariable within certain limits with variation of size of boiler or of quantity of steam made, the larger the amount of work done without increasing this constant expense, the cheaper will the steam be made.

The larger the plant supervised by the engineer the less the total cost per pound of steam made, other conditions of economy being unchanged.

NOTE ON THE ECONOMY OF THE WINDMILL AS A PRIME MOVER.

By Alfred R. Wolff, M.E.

[A paper read before the American Society of Mechanical Engineers, April 21, 1882.]

In the course of professional work I have repeatedly had occasion to investigate the question of the impulse of wind upon windmills, and to observe the economical performance of the latter. From time to time I have published various results of these investigations, but have not given a record of the actual economy of the windmill, the subject-proper of this note. Before, however, setting forth the special economy in the use of the windmill as a prime-mover for small powers, it is well to refer briefly to some publications which may be of interest in connection with the general subject.

For the early history of windmills and a description of European windmills, Fairbairn's "Mills and Millwork" may be consulted to advantage. For a description of the details of American windmills see article on Windmills in Appleton's Cyclopedia of Mechanics, 1880. For an account of experiments on windmills see Smeaton's "Miscel-

laneous Papers," and Coulomb's "Théorie des Machines Simples." For the best angles of impulse and "weather" for windmill blades see *Engineering and Mining Journal*, October 7, 1876, and Appendix I, of this note. The question of the impulse of wind upon windmill blades involves too the consideration of the relation between the velocity and pressure of the wind. A concise summary of this question, useful to no small extent in its reference to the journals containing the original publications of those who have given the subject attention, will be found in a paper by Mr. F. Collingwood, C.E., read before the American Society of Civil Engineers, April 6, 1881, on "An Examination into the Method of Determining Wind Pressures." In Appendix II of this note will be found the tabulated result of the writer's own work in this connection, in which the effect of temperature has received its due consideration. In the *Journal of the Scottish Meteorological Society*, 1880, Mr. F. Stevenson describes some interesting experiments, tending to show the effect of the height of observation above the ground on the relative velocity and pressure of wind. (See also *Engineering*, January 14, 1881.)

Having thus indicated some of the publications, where can be studied those considerations which affect the construction of windmills and which to some extent determine as well its efficiency, I propose now to direct attention to the demonstration of the fact that whatever improvement in efficiency be possible in the future, windmills, as at present constructed, are the most economical prime-movers for those uses for which they are specifically designed.

Designation of mill.	Velocity of wind in miles per hour.	Revolution of wheel.	Gallons of water raised per minute to an elevation of						Equivalent actual useful horse-power developed.	Average number of hours per day during which this result will be obtained.
			25 feet.	50 feet.	75 feet.	100 feet.	150 feet.	200 feet.		
8½ ft. wheel.	15 to 20	70 to 75	6·162	3·016	....	....	....	....	·04	8 to 10
10 ft. wheel.	15 to 20	60 to 65	19·179	9·563	6·638	4·750	....	....	·12	8 to 10
12 ft. wheel.	15 to 20	55 to 60	33·941	17·952	11·851	8·485	5·680	....	·21	8 to 10
14 ft. wheel.	15 to 20	50 to 55	45·139	22·569	15·304	11·246	7·807	4·998	·28	8 to 10
16 ft. wheel.	15 to 20	45 to 50	64·600	31·651	19 542	16·150	9·771	8·075	·41	8 to 10
18 ft. wheel.	15 to 20	40 to 45	97·682	52·165	32·513	24·421	17·485	12·211	·61	8 to 10
20 ft. wheel.	15 to 20	35 to 40	124·950	63·750	40·800	31·248	19·284	15·938	·78	8 to 10
25 ft. wheel.	15 to 20	30 to 35	212·381	106·964	71·604	49·725	37·349	26·741	1·34	8 to 10

In this demonstration, conclusions will be based only on observed facts, or actual running results. I am enabled to do this, inasmuch as

some five years ago, one of the most prominent windmill manufacturers came to me with a few scattered data of actual performances of his mills, which, hovever, were sufficient by means of deductions and analogy, from theoretical principles, to warrant the preparation of the preceding table.

Since the preparation of this table over a thousand windmills have been sold on its guarantee, and in all cases the actual results obtained, both in this country and elsewhere, did not vary sufficiently from those above presented to cause any complaint whatever; a proof that the results as tabulated are very close or certainly not too high. If it be claimed that the horse-power developed appears small, from the standpoint of a (false) prevalent popular opinion, it should be observed in response that the actual results noted in the table are in close agreement with those obtained by theoretical analysis of the impulse of wind upon windmill blades. The manufacturer's own observations during the past five years have led him to conclude that they are correct. It will therefore be just to base the economy of the windmill as prime-mover on the performances recorded in this table, and the expense of obtaining the power will be presented further on.

Conceding for a moment its economy, the possible employment of the windmill as prime-mover is dependent as well on other considerations. The objection urged against the use of windmills is the uncertainty of the motive fluid—wind; but we will see that this objection serves not to prevent, but only to restrict the use of the windmill as prime-mover. Of course it must be acknowledged that there are minutes and hours of total calm, and this restricts the employment of the windmill for such purposes, where either the nature of the work done by the windmill allows of its being suspended during a calm, as work on a farm for instance, or where the work can be stored, as in pumping water for a variety of purposes, or in compressing air, or, as was lately proposed by Sir William Thomson,* for storing electricity by means of dynamo machines and electrical accumulators. There is another restriction which goes into practical effect, namely, that the large size of a windmill for a given power makes it practically desirable only to be used for small powers. But actually it is only designed

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* Presidential address "On the Sources of Energy in Nature Available to Man for the Production of Mechanical Effect," delivered before Section A, of the British Association for the Advancement of Science, 1881.

for the use of small powers, usually between $\frac{1}{25}$ and 4-horse power,* and for such powers it will be shown in this note that it is the most economical and serviceable prime-mover for the purposes for which it is designed.

The difficulty urged by Sir William Thomson to its adoption, in its present state of development for storing electrical accumulators, is the *first cost* of the windmill, but this was doubtless an oversight,† for the *interest* on the capital expended and not capital itself becomes one of the items of current expense in judging of the economy of prime-movers, and, as will become evident from the contents of this note the question of expense of producing power will not prove an objection, but on the contrary the best reason for the introduction of windmills to charge electrical accumulators.

It must be specially mentioned that experience has shown that the wind blows fast enough to run the windmill up to the regulating speed in the above table on an average of eight to ten hours per day of twenty-four hours, and our estimate of work done and expense of power will be based on an actual running of only eight hours per day.

The current expense of any prime-mover, or the cost of obtaining the horse-power developed per unit of time, which alone should form the basis of a comparison of the economy of different prime-movers, consists principally of interest, repairs, and depreciation of plant, cost of fuel, oil and attendance. In windmills the cost of fuel is zero, wind being a free gift of nature. The attendance required for the self-regulating windmills designated in the above table amounts only to filling the oil cups three or four times a month, the work of a few minutes, which any one can attend to. If any account is to be taken of this service, an allowance of fifteen cents a month would really be quite extravagant. In the following table such allowance has been

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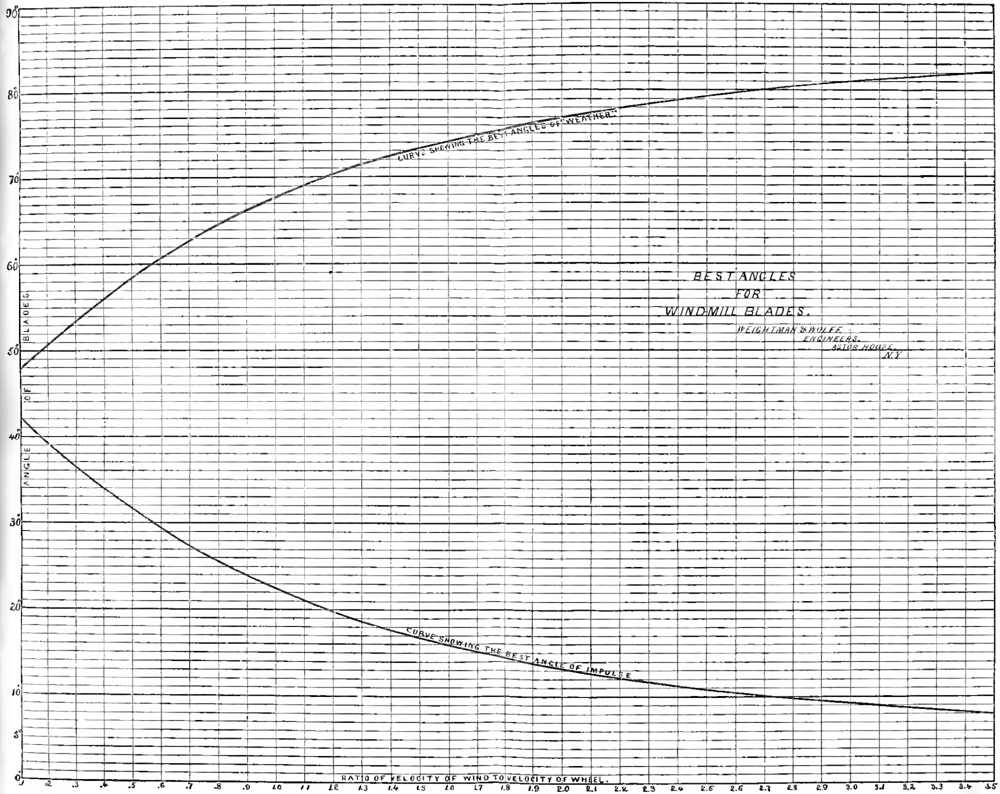
* Coulomb, in his experiments with a windmill of four sails, 70 feet in diameter, breadth of sails $6\frac{5}{8}$ feet, the wind blowing at a velocity of fifteen miles per hour, obtained an actual useful result equivalent to about 7 horse-power.

† In the same paper Sir William Thomson, in estimating the cost of utilizing the power of the Niagara Falls for electric lighting correctly considers the interest on first cost in determining the economical aspect of the question. The oversight noted in the text becomes important and worthy of mention only, inasmuch as any statement of so distinguished and justly esteemed authority as Sir William Thomson is apt to be accepted on the basis of authority alone—and it must be added that the great caution usually displayed by the most eminent living English physicist entitles him *prima facie* to this mark of consideration.


CURVE SHOWING THE BEST ANGLES OF "WEATHER."
BEST ANGLES
FOR
WINDMILL BLADES.
WEIGHTMAN & WOLFE
ENGINEERS.
ASTOR HOUSE.
N.Y.
ANGLE OF BLADES
CURVE SHOWING THE BEST ANGLE OF IMPULSE
RATIO OF VELOCITY OF WIND TO VELOCITY OF WHEEL.

made. Experience has shown that the repairs and depreciation items jointly are amply covered by five per cent. of the first cost per annum. Interest is calculated at five per cent. per annum. The oil used is a very small quantity—a few gallons per year—and is allowed for in the table according to the size of mill. All the items of expense, including both the interest and repairs, are reduced to the hour by dividing the costs per annum by $365 \times 8 = 2920$, the interest, etc., for the twenty-four hours being charged on the eight hours of actual work. By multiplying the figures in column 5 by $\dfrac{365 \times 8}{100 \times \cdot 05} = 584$ the first cost of the windmill in dollars is obtained.

TABLE SHOWING ECONOMY OF THE WINDMILL.

1	2	3	4	5	6	7	8	9	10
Designation of mill.	Gallons of water raised twenty-five feet per hour.	Average number of hours per day during which this quantity will be raised.	Equivalent actual useful horse-power developed.	Expense of actual useful power developed in cents per hour. For interest on first cost. (First cost, including cost of windmill, pump, and tower, five per cent. per annum.)	For repairs and depreciation. (Five per cent. of first cost per annum.)	For attendance.	For oil.	Total.	Expense per horse-power in cents per hour.
8½ ft. wheel.	370	8	·04	0·25	0·25	0·06	0·04	0·60	15·0
10 ft. wheel.	1,151	8	·12	0·30	0·30	0·06	0·04	0·70	5·8
12 ft. wheel.	2,036	8	·21	0·36	0·36	0·06	0·04	0·82	3·9
14 ft. wheel.	2,708	8	·28	0·75	0·75	0·06	0·07	1·63	5·8
16 ft. wheel.	3,876	8	·41	1·15	1·15	0·06	0·07	2·43	5·9
18 ft. wheel.	5,861	8	·61	1·35	1·35	0·06	0·07	2·83	4·6
20 ft. wheel.	7,497	8	·79	1·70	1·70	0·06	0·10	3·56	4·5
25 ft. wheel.	12,743	8	1·13	2·05	2·05	0·06	0·10	4·26	3·2

The number of gallons pumped by the thirty foot and thirty-five foot mills and larger sizes, and the economy of the same are not given in the above table, for the number of larger mills in operation is not sufficient to insure the authenticity of the results thus far obtained. The performance of the thirty foot mill, as far as observed, seems to gravitate to a pumping capacity equivalent to 2·4 horse-power, and an expense of 2·5 cents per horse-power per hour.

When the figures in the table are contrasted with the cost of pumping the same amount of water by other prime-movers, where in addition to expense of interest, repairs, depreciation and oil, there are the greater expenses of fuel and attendance, and often extra insurance

on property owing to the use of steam, the economy of the windmill must be evident to all.

To recapitulate: The figures given in the body of this note are the results of actual experience with hundreds of windmills, and as such, it was believed, would not be without interest. They prove conclusively that at the present time windmills are the most economical prime-movers for the powers and purposes outlined in this note, and for which they are usually designed.

Appendix I.

In a "Dissertation on the Theory and Practice of Windmills," published in the *Engineering and Mining Journal*, October 7, 1876, the writer developed the formula:

$$\tan a = \frac{v}{c} + \sqrt{1 + \left(\frac{v}{c}\right)^2}$$

from which the best angle of impulse might be ascertained.

In this formula

a represents the angle of impulse of the wind upon the windmill blade (or sail), at any point of the blade, for maximum effect.

$v =$ the velocity of the blade (at such point) in feet per second.

$c =$ the velocity of the wind in feet per second.

The accompanying diagram is the graphical interpretation of that formula; the curves showing the best angles of impulse and "weather." The angle of "weather" is the complement of the angle of impulse, and is the angle which an element of the blade or sail makes with its plane of motion. Since there is no difference of effect between that caused by the blades moving against the air, and that caused by the air (or wind) striking upon the blades (assuming the same velocity in both cases), the angles given in the diagram will be found to be those of maximum efficiency for ventilating purposes as well as for windmills.

In the above diagram, the ordinates represent the best angles of weather and impulse expressed in degrees, and the abscissas the ratio of the velocity of the wind to the velocity of the windmill blades. Thus assuming the velocity of the wind to be 31·416 feet per second, the diameter of the wheel to be 35 feet, and the number of revolutions per minute to be made to equal 30, the velocity of the wind-wheel at a point $2\frac{1}{2}$ feet from the centre, of the shaft will be 7·854 feet per second; at five feet from the centre 15·708; at $7\frac{1}{2}$ feet, 23·562, etc.,

and the ratio of the velocity of the wind to the velocity of the sail $\frac{v}{c}$ will at $2\frac{1}{2}$ feet from centre of shaft equal .25; at 5 feet., .50; at $7\frac{1}{2}$ feet, .75, etc. The best angle of weather equals therefore at a distance $2\frac{1}{2}$ feet from the centre of the shaft, 38°; at 5 feet from the centre 32°; at $7\frac{1}{2}$ feet 27°, etc.; and the best angle of impulse equals at a distance of $2\frac{1}{2}$ feet from the centre of the shaft 52°; at 5 feet from the centre 58°; at $7\frac{1}{2}$ feet 63°, etc.

Appendix II.

Table Showing Relation Between Velocity and Pressure of Wind.

Velocity of Wind.		Pressure of wind in pounds per square foot of plane surface, perpendicular to its course, when $P = 2116{\cdot}5$ and temperature of wind =					
Miles per hour.	Feet per second.	0 F.	20° F.	40° F.	60° F.	80° F.	100° F.
1	1·46⅔	·005371	·005147	·004940	·004750	·004571	·004410
2	2·93⅓	·021482	·020586	·019761	·019001	·018294	·017641
3	4·39⅓	·048335	·046318	·044465	·042751	·041166	·039694
4	5·86⅔	·085930	·082345	·079048	·076008	·073185	·070568
5	7·33⅓	·131271	·128668	·123514	·118758	·114335	·110267
6	8·80	·193354	·185287	·177867	·171017	·164675	·158784
7	10·26⅔	·263186	·252205	·242112	·232780	·224148	·216140
8	11·73⅓	·343767	·329423	·316228	·304050	·292774	·282265
9	13·20	·436283	·416945	·400243	·384828	·370555	·357305
10	14·66⅔	·537188	·514772	·494151	·475121	·457498	·441195
11	16·13⅓	·650036	·622908	·597955	·584923	·553600	·533815
12	17·60	·773645	·741357	·711656	·684244	·658865	·635301
13	19·06⅔	·908020	·870122	·835260	·803085	·773296	·745638
14	20·53⅓	1·053166	1·010206	·968770	·931449	·896879	·864814
15	22·00	1·209087	1·158616	1·112190	1·069347	1·029670	·992841
16	23·46⅔	1·375798	1·318354	1·265523	1·216763	1·171621	1·129707
17	24·93⅓	1·553273	1·488425	1·428786	1·373721	1·322751	1·275429
18	26·40	1·741556	1·668839	1·501951	1·540180	1·483066	1·429470
19	27·86⅔	1·940634	1·859596	1·785056	1·716260	1·652571	1·593439
20	29·33⅓	2·150516	2·060705	1·978095	1·901853	1·831270	1·765740
25	36·66⅔	3·362250	3·221749	3·092521	2·973261	2·862857	2·760359
30	44·00	4·845284	4·642662	4·456311	4·284344	4·125157	3·979371
35	51·33⅓	6·600829	6·324565	6·070498	5·836055	5·619046	5·417590
40	58·66⅔	8·630351	8·268791	7·936307	7·627948	7·345581	7·082012
45	66·00	10·935522	10·476877	10·055155	9·666070	9·305975	9·971746
50	73·33⅓	13·518265	12·950585	12·428668	11·947178	11·501614	11·088085
60	88·00	19·525304	18·702993	17·947145	17·250017	16·605025	16·006591
80	117·33⅓	34·981530	33·497300	32·133920	30·877150	29·715020	28·863716

In obtaining the above data attention was paid to the facts that the pressure depends upon both the velocity and the density of the air, and that this density depends upon the temperature, the barometric pressure, and the pressure due to the motion of the air. This table is for the average height of the barometer ($P = 2116{\cdot}5$ pounds per square foot), and for any other barometric pressure the figures in the

table must simply be multiplied by the ratio of the said barometric pressure reduced to its value for temperature of air of 32° F. to 2116·5. Thus letting p_3 = barometric pressure at any absolute temperature t, then $p = \frac{p_3 \times t}{491 \cdot 4}$, and the figures in the table corresponding to wind pressure must be multiplied by $\frac{p}{2116 \cdot 5}$.

For details of the method by which the above table of pressures is obtained, see *Engineering and Mining Journal*, September 23, 1876.

HARMONIC INTONATION OF CHIME BELLS.

By John W. Nystrom.

(Continued from page 432, vol. lxxxiii.)

When all the bells in a peal are made of one standard proportion, and cast of the same kind of metal, the diameter of each bell should be in proportion inversely as the number of vibrations per second of the note to be sounded. This rule holds good for any form of bells, and for any system of intonation.

The following table gives the proportionate number of vibrations of each note in one chromatic octave, and the corresponding proportionate diameter of each bell, according to French harmonic intonation, published in Roret's Encyclopedia, Paris, 1854, which is somewhat different from the German intonation.

In bell chimes the smallest bell is called the *triple*, and the largest the *tenor*, and assuming the diameter of the triple C to be the unit, then the diameter of the tenor will be C = 2, or double that of the triple, whe i the two bells sound an octave. The diameter of the intermediate bells should be in proportion, as noted in column *fraction* in the table, namely B = $\frac{10}{9}$, A = $\frac{6}{5}$ and F = $\frac{3}{2}$ of the diameter of the triple.

It is not necessary that the tenor or triple should sound the note C, but when they are an octave one must be double the diameter of the other, independent of the keynote, and the diameters of the intermediate bells should be in proportion, as shown in the table.

Harmonic Intonation of Chime Bells.

Keynote.		Diameters of Bells.			Vibrations.			Tempered Diameters.
		Fract.	Decimals.	Scale.	Fract.	Actual.	Diff.	
13	C	1	1·000	180	2	528	52·8	1·0000
12	B	$\frac{10}{9}$	1·1111	200	$\frac{9}{5}$	475·2	5·43	1·0595
11	A♯	$\frac{9}{8}$	1·125	202·5	$\frac{16}{9}$	469·77	29·77	1·1225
10	A	$\frac{6}{5}$	1·2	216	$\frac{5}{3}$	440	17·6	1·1892
9	G♯	$\frac{5}{4}$	1·25	225	$\frac{8}{5}$	422·4	26·4	1·2599
8	G	$\frac{4}{3}$	1·3333	240	$\frac{3}{2}$	396	18·86	1·3348
7	F♯	$\frac{7}{5}$	1·4	252	$\frac{10}{7}$	377·14	25·14	1·4142
6	F	$\frac{3}{2}$	1·5	270	$\frac{4}{3}$	352	22	1·4983
5	E	$\frac{8}{5}$	1·6	288	$\frac{5}{4}$	330	13·2	1·5874
4	D♯	$\frac{5}{3}$	1·6666	300	$\frac{6}{5}$	316·8	23·47	1·6818
3	D	$\frac{9}{5}$	1·8	324	$\frac{10}{9}$	293·33	11·73	1·7818
2	C♯	$\frac{15}{8}$	1·875	337·5	$\frac{16}{15}$	281·6	17·6	1·8878
1	C	2	2·	360	1	264	26·4	2·0000

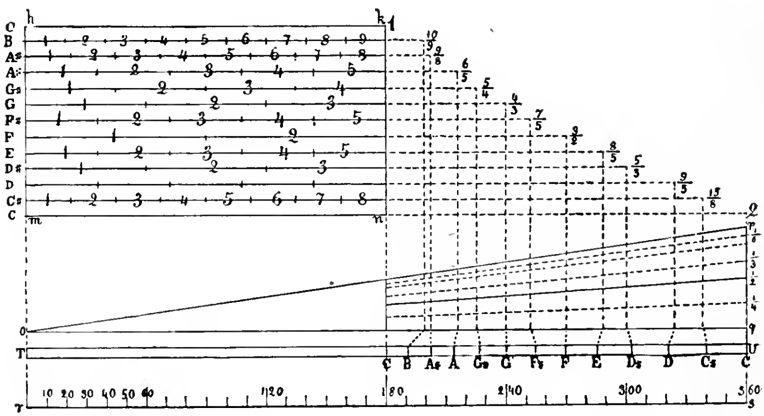
Bell founders have a scale called the *Bell scale*, which they generally keep in great secret, and by which the diameters of chime bells are determined geometrically, without any arithmetical calculation.

The *bell scale* should be laid out on a wooden rod a little longer

than the diameter of the tenor, 2 to $2\frac{1}{2}$ inches wide by 1 inch thick. For a peal of eight bells it is not necessary to draw the lines for the half notes.

The construction of this *bell scale* is represented by the accompanying illustration, namely, as follows:

The line *h*, *k* represents the diameter of the smallest or triple bell, or the unit for the measurements. Draw the perpendiculars *h*, *n* and *k*, *n*, and divide them into twelve equal parts; through each part draw the parallel lines extended beyond the line *k*, *n*, as represented by the dotted lines. There will then be thirteen parallel lines corresponding with the thirteen notes in the chromatic octave, as marked at the line *h*, *m*. From the table we find that the diameter of the bell B should be ten-ninths of that of the triple, C; therefore, divide the line B into nine equal parts, and prolong it one part outside of *k*, *n*, making ten ninth parts, the diameter required for the bell B.



The diameter of the bell A♯ should be nine-eighths of that of the triple C; therefore, divide the line A♯ into eight equal parts and add one part, making nine-eighths, the diameter required for the bell A♯.

The diameter of each bell is obtained in the same way, by dividing the corresponding line into as many parts as the denominator in the table, and add the difference of the numerator.

The diameter of the bell E should be eight-fifths of that of the triple C; then divide the line E into five equal parts and add 8—5=3 parts, which makes the required diameter eight-fifths.

The diameter of the tenor C should be double that of the triple, which is obtained by setting off *m, n,* to 2

From the end of each diameter draw the dotted lines through the triangular scale *o, p, q,* which represents the thickness of the sound bow of each bell.

The scale *T U* is added by the writer to show the corresponding diameter of the bells for tempered intonation, and which scale is laid out from the last column in the table. The slanting dotted lines between *o, q* and *T U* shows the difference between the two methods of intonation. It will be observed that by the harmonic intonation there is very little difference between the bells B and A♯, whilst by the tempered intonation the difference between the diameters, and consequently also between the keynotes, increases in a regular order.

The French bell founders divide the diameter of the tenor into 360 equal parts, of which the diameter of the triple will be 180, and that of the intermediate bells as shown in column *Scale* in the table.

The most sensitive musical ears are freaks of nature, which can never be attained by culture, and the writer does not claim to be gifted with that accomplishment, but thinks that he has sufficient ear for music to perceive that the distance between B and C, as given by the German harmonic intonation, is too large, and that of the French is decidedly wrong. The French harmonic intonation, as given in Roret's Encyclopedia, gives two different values of B, of which one is too low, and the other is like the Stuttgart B.

There are many passages in music, and even in playing the diatonic scale, which evince that the distance between B and C should be half a note for melody. It must be admitted, however, that if B is made higher it will not chord so well with G, but the tempered intonation divides the difference.

The publication of this *bell scale* exposes and records in American literature a secret which is not worth keeping; for a peal of bells made by that scale can never ring good music, not only for the awkward intonation, but principally for the impossibility of properly regulating the *timbre* in the peal by that method. This *bell scale* is, however, published in Roret's Encyclopedia of Founding, Paris, 1854, but nothing is said there about graduating *timbre*, which is of the most importance in bell-ringing.

The harmonic properties of this scale can be easily analyzed by dividing the vibrations of each first note into that of the third or fifth,

in simple chords of two notes. Take, for instance, the simple chords of the *first* and major *third*, and place the major *third* in the numerator and the *first* in the denominator, as follows:

$$\frac{E}{C} = 1{\cdot}25. \qquad \frac{F}{C\sharp} = 1{\cdot}25. \qquad \frac{F\sharp}{D} = 1{\cdot}2857. \qquad \frac{G}{D\sharp} = 1{\cdot}2.$$

$$\frac{G\sharp}{E} = 1{\cdot}28. \qquad \frac{A}{F} = 1{\cdot}25. \qquad \frac{A\sharp}{F\sharp} = 1{\cdot}2444. \qquad \frac{B}{G} = 1{\cdot}2.$$

$$\left(\frac{B}{G} = 1{\cdot}25.\right) \qquad \frac{C}{G\sharp} = 1{\cdot}25. \qquad \frac{c\sharp}{A} = 1{\cdot}28. \qquad \frac{d}{A\sharp} = 1{\cdot}25.$$

$$\frac{d\sharp}{B} = 1{\cdot}3333. \qquad \frac{e}{C} = 1{\cdot}25.$$

When the proportion of vibrations of the *first* and major *third* is as 4 to 5, then the chord is harmonic and gives the number 1·25. In the above there are six harmonic and seven inharmonic chords.

The chord within the parenthesis is the Stuttgart intonation of B, which is also noted in Roret's Encyclopedia, but not adopted on the bell scale.

For the tempered intonation all the chords of the *first* and major *third* give the constant number 1·259.

The chords of the *first* and minor *third* are as follows:

$$\frac{E\flat}{C} = 1{\cdot}2. \qquad \frac{E}{C\sharp} = 1{\cdot}172. \qquad \frac{F}{D} = 1{\cdot}2. \qquad \frac{F\sharp}{D\sharp} = 1{\cdot}1904.$$

$$\frac{G}{E} = 1{\cdot}03. \qquad \frac{A\flat}{F} = 1{\cdot}2. \qquad \frac{A}{F\sharp} = 1{\cdot}1666. \qquad \frac{A\sharp}{G} = 1{\cdot}185.$$

$$\frac{B}{G\sharp} = 1{\cdot}125. \qquad \frac{c}{A} = 1{\cdot}2. \qquad \frac{c\sharp}{A\sharp} = 1{\cdot}2. \qquad \frac{d}{B} = 1{\cdot}234.$$

$$\frac{e\flat}{C} = 1{\cdot}2.$$

For the tempered intonation all these minor chords give the constant number 1·1854.

Six of the above minor chords give 1·2, which is equal to that of two major chords. This, I think, is a positive proof of the incorrectness of the so-called *harmonic* intonation of the chromatic scale, and which, no doubt, is the cause of discordant bell ringing.

No intonation of the musical scale can accommodate equally well both melody and harmony, but the tempered intonation is best for melody and nearest right for harmony in instrumental music. The

writer has tried to divide the octave into different numbers of parts, hoping to conciliate melody and harmony, but all in vain. Nothing better has been found, nor anything near as good as the present division of the octave into twelve equal parts.

The writer inclines to believe that it is so ordained by nature that there should be a difference between melody and harmony, the object of which is to improve instrumental music with a trembling which is very agreeable to ordinary ears, and its defect is perceived only by the most sensitive ears, of which there are very few even among musicians.

Good singers, tenors particularly, often put on this trembling artificially, for the purpose of producing better effect.

In an article on "Experiments on Sound for the Application of Ringing Bells," published in the JOURNAL OF THE FRANKLIN INSTITUTE for April, 1856, the writer gave a table for the tempered intonation with the scientific pitch, making C = 512 vibrations per second; but this table was found to be inconvenient in practice, for which the Stuttgart pitch, with more complete tables, was adopted as explained in the May number of the JOURNAL, 1882, which tables have been in practical use for many years. The formulas for the bells can, however, vary the pitch *ad libitum* whilst using the same tables.

Electric Resistance of a Vacuum.—Edlund thinks that his theory removes all difficulty from the explanation of the electrical and magnetic influences, which different cosmical bodies appear to exert upon one another. If a vacuum is a good conductor of electricity, any electrical disturbance upon one heavenly body must exercise an induction upon others, so that stars and planets may be connected not only through universal gravitation, and through the radiation of light and heat, but also through electric energy. The opposition, which men have hitherto thought to exist between the great height of the aurora above the earth's surface and the electric nature of that phenomenon, loses all meaning. The belief that electricity requires ordinary matter for its propagation must be given up, and the term *conductibility* loses all physical significance. Different material bodies only interpose a greater or less opposition to the spread of electricity, thus exerting not an active but a passive influence.—*Ann der Phys. und Chem.*. xv, 32. C.

AN ORGAN PIPE SONOMETER.

By W. LeConte Stevens.

The discussion of just intonation in connection with the development of the laws of vibration of stretched cords does not occupy much time in the usual course of instruction in acoustics, partly because it is considered as the musician's specialty, and partly on account of the tedious tables of vibration numbers to which the student's attention must be invited. The subject in its relation to the intonation of chime-bells has been well presented quite recently in this journal by Mr. John W. Nystrom.* Some time ago I devised a method of presenting it with the aid of the sonometer, by adjusting division marks on one edge of the sound board to give the proper cord lengths for the natural scale, and on the other edge for the scale of equal temperament. In doing this no attempt was made to adjust the cord lengths of the tempered scale to produce vibration numbers in arithmetical progression with constant differences in different portions of the octave, as recommended by the Stuttgart Congress and criticised by Mr. Nystrom. I deduced the formula, and calculated by aid of logarithms a table of vibration numbers and cord lengths, identical with part of what Mr. Nystrom has just published, assuming that the geometric ratio,

$$r = \sqrt[12]{2} = 1{\cdot}059462,$$

which I had readily obtained, was in general use.† The reciprocal of this,

$$r' = {\cdot}943877$$

gives the common ratio for the geometrical series of cord lengths, by which the twelve semi-tone intervals of the scale of equal temperament are secured. My sonometer was described at the Cincinnati meeting of the American Association for the Advancement of Science, a brief abstract of the description having since been incorporated in the journal of proceedings. The instrument has been still further improved, and a description may now be worth giving.

The resonance-box consists of a double organ-pipe made of spruce,

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* This journal, May 1882, p. 367.

† Airy on sound, p. 224. Macmillan, 1871.

which is rested horizontally on the lecture table. The two embouchures are on opposite sides, one being turned toward the operator, as in Fig. 1. The air-blast, from either the lungs or a pair of bellows, may be forced into either one or both pipes at will through India rubber tubes. The interior dimensions of each pipe are 52 mm. by 62 mm., the length being adjusted to give as fundamental note, C, 132 vibrations per second; the effective length is hence a little over 125 cm., which is the length of the sonometer. At the side of the open end of one pipe is a sliding plate (*a*), by which it may be thrown out of unison with the other, thus producing beats. A stop may be thrust, by means of its handle, half way into one of the pair, converting it at will into a stopped pipe whose fundamental is the same as that of the open pipe of double its length. The union of double organ pipe

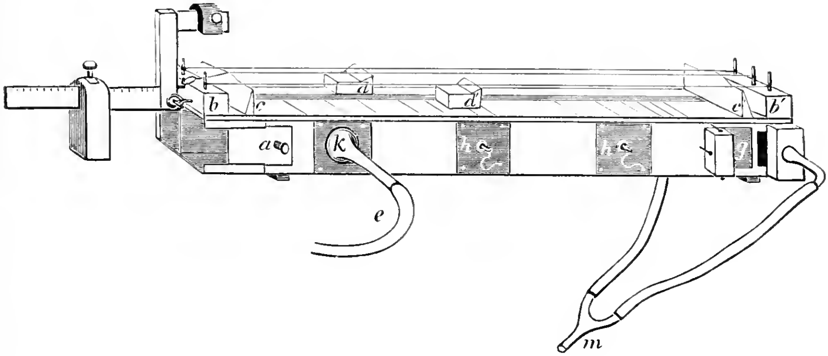

Fig. 1.

with sonometer is attended with some advantages, particularly in connection with the exhibition of Bernoulli's laws, since every note of the harmonic series can be secured with certainty from the stretched wire; and if this be tuned into unison with the fundamental of the organ pipe, a ready standard of pitch is close at hand for comparison with the corresponding harmonics of the organ pipe, which are not always obtained with equal ease, or with entire purity of tone.

The upper wall of the double pipe consists of a single plate of spruce, 5 mm. thick, that forms the sound board of the sonometer. Firmly fixed at each end is a block of hard wood (*b*, *b′*), into which piano pins have been driven for attachment of three steel wires which pass over the fixed bridges (*c*, *c′*). The latter are exactly one metre apart, in contact with the ends of a strip of wood divided at each edge

into millimeters, and occupying the middle of the sound board. Such a strip may be obtained for a trifle from the American Metric Bureau; it not only serves as a guide for the movable bridges ($d\ d'$), but makes it easy to mark off the division lines at their proper places. A longitudinal line divides its surface into two equal parts; that on the side toward the operator is marked off to give cord lengths for the natural scale, by changing the fractions $\frac{8}{9}$, $\frac{4}{5}$, $\frac{3}{4}$, etc., into decimals. The results are indicated, correct to three places, on the millimeter scale. Three octaves in succession are thus marked off: the lines for the first octave extending across to the edge of the sound board, as in Fig. 2, which represents a part of the instrument viewed from above. By multiplying each of these lengths successively by $\frac{135}{128}$ and $\frac{128}{135}$ we obtain cord lengths for the chromatic intervals of the natural scale. These are marked off for two octaves, the lines extending half way to the edge. The other side of the central strip ($e\ e'$, Fig. 2) is marked off through two octaves, to give cord lengths for the scale of equal temperament. There are hence 21 division lines to each octave on one side, and 12 on the other side of the central strip.

Of the three wires, the two outer ones are kept permanently unisonant, or as nearly so as possible, sounding the same note, C, as the fundamental of the organ pipes. That in the middle terminates at the left in a stiff ring, so as to be detached in a moment from the hook against which it is ordinarily kept pulled. The ring may then be attached to a hook projecting from a bent lever, such as is employed with the sonometer constructed by Mr. Ritchie, of Boston, to show the law of variation in tension.

Since the tension of the outer wires is kept constant, each division mark in both natural and tempered scales is distinctly labeled, as shown in Fig. 2. The movable bridges are painted black at their front edges, so as to contrast strongly with the white spruce on which they slide. Suppose the bridge, d', to be adjusted so that its wire sounds E of the natural scale, while its companion, d, is adjusted to give E of the tempered scale. The difference in pitch is nearly a comma, and can be detected at once by a good ear. But this is additionally made visible by turning the sonometer toward the audience and resting it on its narrow side; the difference in position of the two bridges being easily detectible even when the ear fails to distinguish between the two sounds. Every note in the two scales can thus be compared in a few moments, starting with C as key note.

The necessity for temperament, and yet the unavoidable error of a tempered scale, is still better shown by taking some derived key for comparison; for example, that of G. For this purpose a separate strip (f, f' Fig. 2), properly marked off, is placed at the side of the central strip, the movable bridge being grooved below to slide over it. It is prepared by marking a strip whose length is $\frac{2}{3}$ metre at distances $\frac{8}{9}$, $\frac{4}{5}$, $\frac{3}{4}$, $\frac{2}{3}$, $\frac{3}{5}$, $\frac{8}{15}$, $\frac{1}{2}$, and then discarding the unmarked half. Placing the initial extremity of this scale in contact with the division mark, G, of the tempered scale, which in this case sensibly coincides with that of G on the natural scale, it is seen that the second note, if correctly tuned, would be a trifle higher than tempered A, and decidedly higher than natural A; the third would be lower than tempered B and unisonant with natural B; the fourth unisonant with both tempered and natural C, etc. Such a strip can be constructed for each one of the derived keys employed in music, though the principle is sufficiently shown with but one.

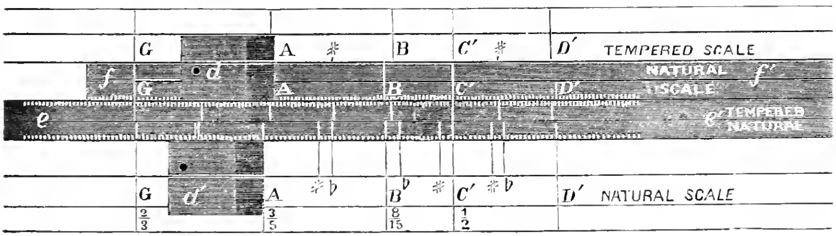

Fig. 2.

The division marks, $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, $\frac{1}{5}$, $\frac{1}{6}$, etc., each labeled with the name of the corresponding note, C′, G′, C″, E″, G″, etc., as well as with the figures composing the fraction, render it easy to obtain with quickness and accuracy the first dozen notes of the harmonic series, besides facilitating experiments on co-vibration.

To obtain the harmonic series from the open organ pipe it is found convenient to modify the size of the embouchure, and also the diameter of the pipe. For this last purpose a piece of wood, 120 cm. long, 6 cm. wide, and 2 cm. thick, is thrust into the pipe next the operator, thus diminishing the volume of air set in motion, and increasing the ratio of length to width. A sliding plate (g, Fig. 1) of thin sheet-iron serves to narrow the embouchure at will. Eight or ten successive notes of the harmonic series are thus secured and compared at the same time with those obtained by aid of the wire and labeled scale.

The stop can then be thrust into one pipe, and several of the odd series of harmonies elicited.

The wall of the pipe next the operator is perforated with three small holes, at distances approximately $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, from the open end. These are kept stopped with plugs, which may be removed at will. Immediately around them the wall is covered with sheet rubber (h, h,) to secure an air-tight fit for the mouth of the funnel (k) from which a tube (l) conveys waves to a manometric capsule. The position of nodal points in the air column is thus shown. By fitting the tube (l) upon a Y-tube, like that shown at m, and interposing between this and another Y-tube a pair of India rubber tubes, one of which is longer than the other by a half wave length, making allowance for friction, the apparatus is readily utilized for illustrating interference, with the aid of the manometric flame.*

New York, May 4, 1882.

ANALYSIS OF HELVITE FROM VIRGINIA.

By Reuben Haines.

[Read before the Chemical Section, Franklin Institute, May 2, 1882.]

The writer was requested by Mr. Henry Carvill Lewis to analyze a mineral he had lately found among others at the mica mines, near Amelia Court House, Virginia, a locality which has become remarkable for its rare minerals. It appears to be Helvite, a rare mineral hitherto found only in Europe; in Saxony, Norway and Finland. It is a silicate of glucina and manganese, containing ferrous sulphide and manganese sulphide. It occurs in yellow crystals and crystalline masses associated with orthoclase and garnet.

The following mineralogical determinations were made by Mr. Lewis. The crystals were shown by the polariscope to be isometric, but were not sufficiently perfect for angular measurement. Hardness about 6; color sulphur yellow; lustre somewhat resinous; partially translucent; fusibility about 4, with intumescence to a brown glass. The mineral gives no water in closed tube; with fluxes reacts for manganese; soluble in hydrochloric acid with evolution of hydrogen sulphide and separation of gelatinous silica.

The specific gravity which I determined myself was 4·306.

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* We are indebted to *Am Jour. Science and Arts* for the use of the cuts illustrating this article.

The results of my analysis are as follows:

Silicious gangue,	9·22	32·32 per cent.
SiO_2 (gelatinous),	23·10	
BeO,	11·47	
Al_2O_3,	2·68	
MnO,	45·38	
FeO,	1·85	
CaO,	·64	
K_2O,	·39	
Na_2O.	·92	
S,	4·50	
Ignition (moisture),	·30	
	100·45	
Less oxygen replaced by sulphur	2·25	
	98·20	

The total amount of the mineral obtained was scarcely more than one gram. About ·72 gram was reserved for general analysis, and the remainder was used for determination of specific gravity, sulphur and moisture.

The method of analysis pursued was as follows:

The powdered mineral was dissolved in hydrochloric acid, evaporated to dryness, filtered, and the residue treated on the filter eight times with hot concentrated solution of sodium carbonate, and finally washed thoroughly with hot water. Ignition of the residue gave the siliceous gangue insoluble in acid and in sodium carbonate. There was thought to be less risk in washing on the filter than by boiling up in a beaker and refiltering. The total silica plus gangue was obtained by weighing the residue of silica from the estimation of sulphur for which about $\frac{1}{10}$ gram was used. The difference between these two estimations gave the gelatinous silica. The Fe_2O_3 and Al_2O_3 were separated from MnO and BeO by first repeated precipitation by ammonia, and finally by protracted boiling with concentrated solution of ammonic chloride repeated four or five time to dissolve out all the glucina (Berzelius' method). The Fe_2O_3 and Al_2O_3 were weighed together and titrated by permanganate in the usual way. The glucina and manganese were separated by double precipitation by ammonia, being careful to avoid excess, heating as short a time as possible and filtering

soon to avoid resolution of the glucina. The manganese was precipitated by bromine and then by sodium phosphate and was weighed as pyrophosphate. The filtrate from the calcium oxalate, after testing for magnesia, was boiled with barium hydrate to obtain the alkalies which were separated by platinum chloride, and the ignited platinum weighed.

The sulphur was separated and oxidized by dissolving the mineral in hydrochloric acid, to which bromine had been added.

For the specific gravity dermination ·28 gram was used. It was made in a ten-gram specific gravity bottle with great care as to temperature and all other necessary precautions.

The moisture was determined in a separate portion the weight of which was 83 milligrams, by direct absorption in a chloride of calcium tube attached to a combustion furnace.

By reference to Dana's mineralogy, it will be seen that my determination of the specific gravity differs materially from that given for Helvite. Yet in all other respects, both physical and chemical, except the manner of regarding the silica, the analysis given above agrees very well with that mineral. Dana gives the specific gravity as 3·1 to 3·3; mine is 4·3. Any slight impurity in my specimen in the form of garnet or feldspar would tend to lower instead of raising the specific gravity.

As regards the silica, it will be noticed that in former analyses the amount given is 33·26 to 35·27 per cent. in two analysis by Gmelin; 33·13 per cent. in one analysis by Rammelsberg, and 30·31 per cent. in one analysis by Teich. If the gangue and gelatinous silica in my analysis are added together we have total silica 32·32 per cent. It appears to me, however, that either we must regard the gelatinous silica alone as a legitimate part of the true species and consider the "gangue" as accidental impurity, or we must consider the silica of the true mineral as existing in two distinct molecular conditions. The latter hypothesis is scarcely tenable, while the former would require a formula quite different from that given by Dana for Helvite.

THE ABSORPTION OF METALLIC OXIDES BY PLANTS.

By Francis C. Phillips.

[Paper read before the Engineers' Society of Western Pennsylvania, Tuesday, February 21, 1882.]

The question how far the vital processes of plants are influenced by the various mineral compounds presented by the soil to their roots has long been under discussion in physiological botany, but further than to establish the fact that the presence of certain compounds in soil tends to increase the nutritious elements, and promote the growth of particular vegetables, little has been done towards a complete solution of the problem.

It is well known that potash tends to increase the quantity of starch, that silica strengthens the stems of the grasses, that oxide of iron is essential to the production of leaf-green, that phosphates increase the fertility of the soil for cereals, but even as regards these constant elements of every soil, very little can be positively asserted of the precise influence of any one, in the economy of the plant.

Concerning the part played by the rarer elements, caesium, rubidium, copper, nickel, manganese, zinc and barium, in the assimilation of carbon, nitrogen, and the functions of nutrition, and whether they are beneficial or injurious, nothing whatever is known, although modern refinements in chemical methods have led to their frequent detection both in soil and in plants. That so important a problem should have remained almost wholly unsolved must be attributed chiefly to the very great difficulties which are met in any experimental investigation, but also to the fact that the few investigations published have been carried out, in most cases, for the purpose of proving that vegetation had been injured by metallic compounds traceable to a metallurgical works, and with the special purpose of founding a claim for damages, rather than to solve a scientific problem. The study of the influence of metallic compounds on plants has recently acquired great practical importance, from the fact that many manufacturing processes, more especially those employed in the smelting of lead and copper, and arsenical ores of various metals, have given rise to a gradual impregnation of the soil with such metals, and to the consequent poisoning of vegetation and animals.

In almost all cases where furnaces for the treatment of such ores have been erected, there has followed a serious injury to vegetation, caused by the metallic vapors and dust escaping from the flues; while the lawsuits instituted to recover damages have brought forward many interesting facts as to the extent of vaporization of metals, the necessity and difficulties of providing proper means for condensing the noxious fumes, the evidence has seldom furnished any definite information as to the more general question at issue.

The possibility of injury to plants from such sources has been denied under an assumption that plants, like animals, possess a certain discriminating power, and that they are able to select and take up through their roots, such elements of the soil as are nutritious, and to reject all else, a view which is very commonly accepted, and has been held by high authorities.

With the very much less complete condensing apparatus in use in former times, the injury caused by such establishments was far greater than at present, but even at smelting works where the most improved machinery is in use, it is often difficult to prevent the escape of large quantities of poisonous mineral compounds, which in the shape of dust may be carried many hundred yards and scattered with injurious effects upon vegetation.

As early as the year 1668 mention is made of the injury to pastures, caused by lead fume, by Joseph Glanvil, who published a description in the "Philosophical Transactions" of the smelting of lead ores in the Mendip Hills.

This author says "there is a flight in the smoak, which, falling upon the grass, poysons those cattel that eat of it. They find the taste of it upon their lips to be sweet, when the smoak chances to fly in their faces. Brought home and laid in their houses, it kills rats and mice.

"If this flight mix with the water in which the oar is washed, and be carried away into a streame, it hath poysoned such cattel as have drunk of it after a current of three miles."

Richard Watson, in his "Chemical Essays," published in 1799, calls attention to the saving to be effected, and the protection afforded to pastures, by the use of long horizontal chimneys, for the condensation of lead fume, in Derbyshire.

"But so difficult is it," says this author, "to wean artisans from their ancient ways that I question whether any of them would ever have adopted the plan they approved, if an horizontal chimney which

was built in Middleton Dale to protect pastures from the smoke of the furnace, had not given them full proof of the practicability of saving the sublimate of lead which is lost in the ordinary method of smelting."

Among more recent cases, the following, cited by Taylor, in his "Treatise on Poisons" (3d American edition, p. 424), is of interest: "It was alleged on the part of the plaintiff that a large number of sheep and cattle had been destroyed by fumes of lead escaping from a chimney on the defendant's works. The case involved this curious point, namely: admitting the sheep and cattle to have been destroyed by lead, whether the lead was deposited on the herbage from the defendant's chimney, or taken up by the plants from the soil, and incorporated with their tissues. The condensing arrangements at the lead works were found to be almost absolutely complete, and there was not the slightest appearance of a deposit of white lead on the herbage. But it was found that the herbage was impregnated with lead, and that seeds sown in the leaden soil, brought for this purpose to London, produced plants containing lead. The soil had derived the lead from ancient mineral workings."

Dr. Wilson ("Edinb. Monthly Journal of Medicine," 1852), in a case somewhat similar to that cited by Taylor, of cattle poisoning by lead, found the herbage to contain the metal, and that beans grown upon a portion of the soil were impregnated in the same manner.

The results seem to point very clearly to the possibility of the absorption of lead by the roots of plants.

An exhaustive investigation into the action of copper and zinc on vegetation has been made by Dr. Freytag, of the Agricultural Laboratory in Bonn,* and the results published in an official report upon the injury alleged to have been caused by the smelting furnaces of Mansfield. In the neighborhood of Mansfield, furnaces have been in operation for several centuries, and the soil in many places has in consequence became greatly deteriorated as regards its fertility, being charged with as much as 10 lbs. of oxide of copper and 24 lbs. oxide of zinc, to the ton of earth. In order to test the influence of these metals upon the nutritive qualities of the crops, Freytag made comparative analyses of clover and grass grown in the neighborhood of the smelting

* "Wissenschaftliches Gutachten über den Einfluss, welchen die Hüttenwerke der Mansfelder Kupferschieferbauenden Gewerkschaft auf die Vegetation und indirect auf Menschen und Thiere ausüben" Von Dr. Moritz Freytag. Eisleben, 1870.

furnaces, and of similar plants grown five miles distant, but under as nearly as possible the same conditions of temperature, moisture and manuring. The plants from the neighborhood of the furnaces differed in the following points from those grown at a distance.

1. They contained in their ashes varying quantities of the oxides of copper and zinc, as much as 0·2 per cent. oxide of copper, and 0·36 per cent. oxide of zinc.

2. There was a larger per centage of sulphuric acid, attributed by Freytag to the fact that the copper and zinc occur in the soil as sulphates.

3. The proportion of nitrogenous bodies was greater by 25 to 30 per cent. (2 per cent. of the dried plant). As regards the assimilation of nitrogen, therefore, the metallic sulphates were apparently beneficial.

Very interesting experiments have been made by Freytag upon the capacity of plants to absorb solutions of metallic salts.

Beans, peas and other seeds were allowed to germinate in a solution containing nutritious matters, and after maturing, were transferred to solutions containing arsenious acid, the sulphates of iron, cobalt, nickel, zinc and copper.

The result was that a solution containing $\frac{1}{80}$ per cent. arsenious acid proved fatal, as was also the case with $\frac{1}{25}$ per cent. sulphate of cobalt, $\frac{1}{15}$ per cent sulphate of nickel, $\frac{1}{50}$ per cent. sulphate of zinc, $\frac{1}{5}$ per cent. sulphate of iron.

No injurious effects were produced by more dilute solutions, the plants continuing to thrive until the poisonous limit of concentration was reached, when they rapidly withered and died.

In all cases there were found in their tissues small quantities of the respective metals in whose solutions they had been grown.

Freytag says: "I have found that plants growing in solutions of metallic salts are killed when the concentration reaches a certain degree, which is in all cases below 1 per cent. of the solution, and this statement applies equally to those salts which are essential to plant life. If we accept this as equally true of plants growing upon soil, it follows that the moisture of the soil must contain very small traces of mineral salts in solution, and by experiment it has been shown that the watery extract of a soil which is charged with salts of the heavy metals always contains less than the fatal dose of such metals."

Freytag thus sums up:

"It has been fully demonstrated that plants are not capable of

selecting from the substances presented to their roots, that they are on the contrary, compelled to take up all matters alike, which are in a form fitted for absorption, but that matters insoluble in the moisture of the soil are never taken up in sufficient quantities to endanger the life of the plant."

Freytag claims as his own, the theory of non-discrimination of plants, but Liebig in his "Agricultural Chemistry," (4th English edition, page 66), states that "all substances in solution in a soil are absorbed by the roots of plants, exactly as a sponge imbibes a liquid, and all that it contains, without selection."

Freytag has detected zinc and copper in the leaves of oaks and birch trees in the Mansfield district, and in a series of experiments it was found that zinc added to soil in the form of carbonate is absorbed by rye, wheat and maize, and is deposited in the leaves, stems and seeds. Many plants growing near zinc mines absorb considerable quantities of oxide of zinc, and in two well-known cases new varieties are considered to have been produced by soil containing zinc, one a shepherd's purse (Thlaspi alpestre, variety calaminaris), the other a violet (Viola tricolor, variety calaminaris.)*

The latter plant is considered by some authorities to be a distinct species. The ash of the leaves of this violet contains 13 per cent. oxide of zinc. Both of these plants are confined to localities where zinc is an element of the soil, and the zinc seems therefore to be an essential constituent.

Among the strongly poisonous metals, zinc appears, according to the investigations published, to be the most readily absorbed by plants. It is of singular interest, however, that experiments conducted in the botanical garden at Erlangen, have led to a negative result, as regards the possibility of its absorption, contradicting, therefore, those obtained by Freytag.

In the report of the Commissioner of Agriculture (Washington, 1875), some experiments are described upon the action of Paris green on vegetation. Peas were sown in soil containing varying quantities of Paris green. No injurious effects were produced where the quantity of the arsenical compound was less than 900 lbs. per acre of soil. When present in larger quantity, the plants were feeble and were smaller in proportion as the arsenic was increased. With 1½ tons of Paris green to the acre the seeds failed to germinate. The plants were

*Johnson, "How Crops Grow," page 196.

tested for arsenic but were found to have not absorbed even traces of the metal recognizable by Marsh's test.

These results involve therefore a direct contradiction of Freytag's theories, both as regards the non-absorption of the metal, and as regards the vital processes of the plant. According to Heckel ("Comptes Rendus," vol. lxxx, p. 1172), water containing $\frac{3}{100}$ per cent. of arsenious acid prevents the germination of seeds and destroys the embryo plant.

For the purpose of throwing some light on this difficult problem of the influence of metallic oxides upon plant life, a series of experiments was carried out during last spring in the greenhouse of the Allegheny park, by the kind permission of the superintendent of the park, Mr. William Hamilton.

The object of these experiments was to determine, firstly, whether any injurious effects are produced upon plants by being grown in soil impregnated with certain metallic oxides; secondly, whether plants in a perfectly healthy state will absorb such oxides through their roots. In the early spring the greenhouse was filled with very young plants, in a vigorous condition of growth, which were being reared for the purpose of supplying the park in the summer. The plants selected were geraniums, coleas, ageratums, achyranthes and pansies. This selection was made, not with reference to any special peculiarities of the plants, but for the reason that there were thousands of other plants of the same kind, and all equally advanced in growth, on the tables of the greenhouse, which afforded an opportunity for a close comparison of those grown upon poisoned soil with others grown under normal conditions.

The compounds used were the carbonates of zinc, copper and lead, and as an arsenical compound, arsenate of lime. These compounds are almost absolutely insoluble in pure water.

The method of setting the plants was that commonly employed by gardeners in transplanting. Young plants, with their roots as nearly as possible intact, were placed in flower pots, and soil previously mixed with a weighed quantity of the metallic compound was poured in and pressed down around the roots. The first series included ageratums, which were grown in soil containing $\frac{1}{2}$ per cent. white lead.

The second series consisted of geraniums, which were grown in soil containing $\frac{1}{2}$ per cent. carbonate of zinc.

The third series included achyranthes. The soil supplied to them contained $\frac{1}{2}$ per cent. carbonate of copper.

The fourth series were coleas, which were grown in soil containing $\frac{1}{2}$ per cent. arsenate of lime.

The fifth series included coleas, grown in soil containing $\frac{1}{4}$ per cent. arsenate of lime.

The sixth series were pansies, grown in soil containing $\frac{1}{2}$ per cent. carbonate of zinc.

All these plants enjoyed the usual careful greenhouse nursing, and as regards temperature, moisture and fertility of the soil, the conditions were absolutely the same as in the case of the other plants, excepting the poisonous influence to which their roots were exposed.

The progress of each plant was watched and a record kept. On the 10th of June, eleven weeks after the commencement of the experiments, the plants were cut off above the roots, and those of each series subjected to analysis, with the following results:

The ageratums, grown in leaden soil, matured and produced flowers as early as the most advanced of those grown in ordinary soil. Their roots were very abundant and healthy, the only noticeable effect of the lead being that the leaves were of a yellowish hue. The analysis showed that lead had been absorbed in small quantities.

In the second series geraniums were reared in soil impregnated with carbonate of zinc. The plants were in every respect normal, bore flowers and produced abundant roots.

The analysis showed considerable quantities of zinc.

In the third series, achyranthes were grown in soil containing carbonate of copper. The effect of the copper was not visible in the plants at first, as they continued to grow rapidly, and were normal in color. But in maturing, the bright leaves became darkened. It was found that the copper had killed the original roots, and totally arrested the development of new ones. The plants had apparently been nourished from the air alone. Very small quantities of copper were found in their ashes.

The most strongly marked results were produced in the case of the arsenic. In the fourth series, coleas were grown in soil containing $\frac{1}{2}$ per cent. of arsenate of lime. The effects of the poison were visible in a few days, the plants languishing and producing but few leaves. In the course of two weeks all were dead.

In the fifth series, coleas were reared in soil containing $\frac{1}{4}$ per cent. of arsenate of lime. The plants were feeble from the first, produced but few leaves, which were normal in color. Although they endured

with greatly diminished vitality, no increase in growth took place, and the stems were not strong enough to remain erect. In all cases the arsenic had totally destroyed the roots. Traces of arsenic were found in the analysis.

In the sixth series, pansies, grown in soil containing carbonate of zinc, produced abundance of roots and continued healthy. Analysis proved the presence of zinc in considerable quantities.

In view of conflicting statements of authorities, further experiments on a large scale, and extended to a wider range of plants, grown under varying conditions, would be needed to establish any general laws in regard to the absorption and influence of metallic poisons contained in soil upon vegetation. The discovery of these laws would probably lead to the discovery of methods for the prevention of such influences, so far as they are of a dangerous character.

From the experiments detailed above it seems safe to conclude, however:

1. That healthy plants grown under favorable conditions may absorb through their roots small quantities of lead, zinc, copper and arsenic.

2. That lead and zinc may enter the tissues in this way without causing any disturbance in the growth, nutrition and functions of the plant.

3. That the compounds of copper and arsenic exert a distincly poisonous influence, tending, when present in larger quantity, to check the formation of roots, and either killing the plant or so far reducing its vitality as to interfere with nutrition and growth.

In the case of the heavy metals, copper, zinc, arsenic and lead, it seems to be probable that their oxides may under certain circumstances become deposited in the tissues of the plant. As to the manner in which this takes place, authorities differ.

It is supposed by Freytag and others, that plants absorb all soluble matters indiscriminately, through their numberless rootlets, that the absorption of poisonous metals causes no disturbance until a certain degree of concentration is reached, when the plant rapidly withers and dies; that plants are therefore spared the sufferings of chronic poisoning, but are very susceptible to acute poisoning, which is invariably fatal; while it is held by others that plants absorb only such elements as are essential and nutritious, refusing to take up what is poisonous

or innutritious; metallic compounds found in the analyses are therefore to be traced to atmospheric deposit adhering externally.

The theory of Freytag seems to have the weight of facts in its favor, and if it is possible that crops may become charged in this way with poisonous elements of the soil, it becomes a matter of the highest importance that wherever there is danger of such impregnation the most efficient means be employed for its aversion; for soil once impregnated with copper, lead and zinc, may year after year bear crops poisoned in the same manner.

APPLICATIONS OF THE PRINCIPLE OF THE PHONO-DYNAMOGRAPH.

By William B. Cooper.

[A Paper read at the Stated Meeting of the Franklin Institute, May 17, 1882.]

Upon the evening of the last meeting of the Institute, I gave a brief description of a device for augmenting the dynamic effect of the vibrations of diaphragms, and directed attention particularly to its application to the production of a record of such pulsations in much thicker metal than was heretofore thought possible; on account of the interest manifested by those then present, I have brought the device again before you with the view of entering more at length into its applications.*

When a cord is passed over a revolving pulley, it is well known that there is a pull upon one side proportioned to the character of the surfaces in contact and the pressure upon them. This pull is due to the friction of the surfaces upon each other, and increases in approximately (if not exactly) the rame ratio as the pressure; now, if the pulley is loose upon the shaft and we draw upon a cord passing over it, we have the same force exerted at the other end of the cord minus the friction at the shaft; if, however, the pulley is attached to the shaft and is rotating towards the end drawn upon, then the result at the other end will be the force applied, plus the amount derived from the friction upon the surface of the pulley. This is the principle of

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*Since the above was presented, Mr. Cooper has devised a method of accomplishing this result in a radically different manner, although upon the same general principle. This he intends to bring before the Institute at an early day.

my device. To one end of a wire or band, *B*, Fig. 1, I attach a diaphragm or other pulsating body, *C*, and then give a half turn or several turns around a drum or pulley, *A*; to the other end may be attached a lever, *D*, having a point adapted to the indentation of sheet-metal passed under it at a uniform speed; this may be accomplished by any suitable mechanism. In this form I have termed it the "Phonodynamograph," and my experiments have already resulted in embossing brass of the thickness of writing-paper by the impact of the voice upon a diaphragm of the size used in the phonograph.

This principle is, without doubt, applicable to the telephone, both for the purpose of increasing the intensity of the electric impulses transmitted, and augmenting their effects at the receiving station. At the transmitting station, for example, the same, or by means of leverage, a greater amplitude of vibration may be given to a stouter dia-

Fig. 1.

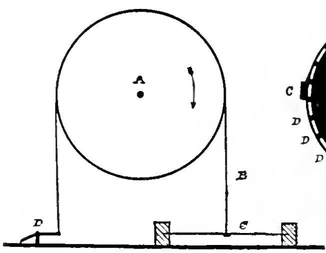
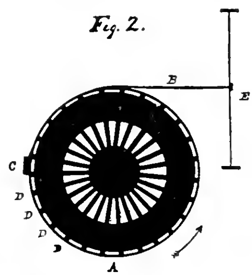


Fig. 2.



phragm, or an armature controlled by a spring, playing before the poles of a magnet. It is manifestly applicable, however, to any form of transmitter in which increased power is advantageous. By it the telephone may be rendered available for greater distances.

Having augmented the electric impulse at the transmitter, we may add to it an increment derived from an auxiliary power at the receiver. This may be done in several ways: the vibrations of a receiving diaphragm, or an armature in combination with a spring may be augmented and made to operate a second diaphragm or a recording point. As the dynamic effect of the telephonic impulse is at best but feeble, I have devised a method of dealing with it which appears to me cannot but produce some very striking results.

If a number of electro-magnets, *D*, *D*, *D*, *D*, Fig. 2, preferably of the horseshoe form, are arranged radially in a drum or pulley, *A*,

composed of some non-magnetic substance, at right angles to its plane of motion, with their poles flush with its face, it is clear that if an armature, *C*, is placed in contact with the face of the drum and it is rotated, the armature will be drawn in the direction of the motion of the poles of the magnets whenever an electric impulse passes through their helices; the extent of this motion will depend upon the inertia of the armature, the resistance applied to it, and the strength of the electric impulse, etc. If the number of magnets is such that the distance between their poles at the face of the drum is somewhat less than the width of the armature, and each succeeding magnet makes electric connection before the preceding one has parted from the armature, then there will be a continuous draft upon the armature as long as the electric impulse lasts, subject to the above-mentioned influences; there will clearly be a sensitiveness to slight magnetization owing to the continuous intimate contact of the armature with the poles of the magnets. If we now connect to the armature a wire or band, *B*, and give it one or more turns around the drum in the opposite direction to its motion, we will have the draft upon the armature augmented by an increment derived through the agency of friction from the power applied to rotate the drum. The other end of the wire or band may be attached to a diaphragm, *E*, or it may be connected to recording mechanism.

At the work-end of the wire or band the normal tension may be reduced to a minimum by an adjustable spring, while the friction may be increased by increasing the number of coils, the size of the drum, or the nature of the surfaces. A light spring may also be found advantageous at the slack end under some circumstances.

Instead of a wire or band, a chain, one or more shoes hinged together, or coupled by a cord, wire, band or chain, may be used.

The magnets used in the drum may be small, as magnetization and demagnetization is said to be more rapid in small than in large cores. If made in the horseshoe form, as suggested, their poles should be sufficiently separated to leave a zone of uninterrupted friction surface in the middle of the face of the drum. The face of the armature in contact with the drum has a notch or recess over this middle zone to give the band free play.

The principle applied in the above cases is also applicable to the mechanical telephone. It may also be used to reproduce the record in increased sound, as by giving a diaphragm greater amplitude of

motion, a louder tone results. A large diaphragm having a funnel or trumpet attached to it, through the intervention of this device may, by means of leverage, be made to vibrate with greater amplitude than the smaller diaphragm at which the pulsations originate. This will be a simple method of increasing the power of the voice in the many cases where that is desirable.

I have also devised improvements in recording the vibrations of diaphragms, etc. A small burr or circular saw, revolving at considerable velocity, may be used, its plane of motion being at right angles to that of a strip, plate or cylinder against which it is pressed by the pulsations of a diaphragm; or, it may be made to notch the edge of a strip. If it is desirable the burr or saw may be stationary, and a strip may be pressed against it by a small roller, or other device, operated by the diaphragm.

In the case of indenting metal with a stylus, the metal may be acted upon while softened by heat. A strip might be heated by an oxyhydrogen jet just before passing under a stylus of some refractory substance; and in the case of a strip of steel, it might be tempered by passing it immediately into water, or oil, or cotton waste, or some similar substance saturated with them. In this case, also, the stylus or point may be fixed and the strip pressed against it, if that method should be found more desirable.

Distribution of Dark Heat.—P. Desains has investigated the distribution of heat in the obscure region of the solar spectrum. The diathermancy of the air is continually varying on account of the variable degrees of moisture which it contains. The radiations of the luminous part of the spectrum are only slightly absorbed, but the dark rays are largely so, and in a ratio which generally increases with the length of the wave. In order to measure these influences, the observations have been compared with others upon the transmissibility of the total solar heat through a uniform thickness of water. Prisms of flint and crown glass and rock salt, of which the indices have been accurately determined, are employed in these measurements. Desains has already obtained data which enable him to construct the curves which represent the distribution of heat in the dark spectrum, and he proposes soon to publish some valuable comparative results.—*Comptes Rendus*, civ, 1144. C.

REMARKS MADE AT THE CLOSING EXERCISES OF THE DRAWING SCHOOL, MAY 18, 1882.

By Coleman Sellers, Jr.

It seems perhaps scarcely necessary to try to offer any encouragement to those who are doing successfully so excellent a work as that whose results we have before us this evening—hardly necessary to commend the scholar for making the most of the opportunities offered him or the instructor for doing his duty faithfully and thoroughly. But it may be of interest for both to receive the assurance that, in the opinion of those who have watched their progress, the work they have done has been in the direction from which they may expect to obtain the greatest benefit. The term "drawing" comprehends operations vastly dissimilar—in fact, it comprehends operations so dissimilar and results so diverse that it can scarcely be described by a general definition less comprehensive than that of Hamerton who defined drawing as a "*motion which leaves significant marks.*" This alone will include that vast range which lies between the finished work of the great painter and the crude sketches of the savage, or the cruder efforts of childhood with pen and pencil.

In every case the drawing depends not alone upon the skill of the draughtsman, but also upon the facilities at his disposal and the kind of information he desires the drawing to impart. For example, the drawing which is made by the gas-fitter, by which to get out his pipes and fittings, bears to the uninitiated eye no resemblance to the completed work, but it conveys to the mind of one skilled in the art a clearer notion of what is wanted than the most elaborate picture could convey.

Scientists tell us that the earliest draughtsmen of whom we have any knowledge were the cave-dwelling men of Europe, who belonged to a race that passed away hundreds or perhaps thousands of years before the commencement of the era in which we live. This curious people, about whose lives and appearance our knowledge is at best only careful guessing, have left behind them drawings made with a sharp piece of flint, most likely, upon the bones and teeth of the strange animals they slew, and these drawings are said to convey correct ideas of

form and appearance, and give us some proper notions of what they saw around them. In fact, so good are they that the naturalist is able to identify the *genera* and *species* of the animals represented. In this respect these drawings were unlike a child's early sketches, although perhaps those primitive people were but children in the scope of their minds and faculties. The child, you know, generally begins by drawing man as a couple of triangles joined at their points, or sometimes like a "figure eight," with four straight marks for arms and legs.

As I have said, industrial drawing varies to suit the different crafts or trades with which it is associated. The pupils of the Franklin Institute Drawing Schools are mainly those who desire to obtain a knowledge of that branch of the art of drawing which applies most directly to the occupations of the machinist and the pattern maker. Now it so happens that the professional teachers of and writers on mechanical drawing, as this kind of drawing has been called, have generally not been those who have had occasion to make and use drawings in the way that draughtsmen and machinists use them and make them. The consequence of this has been that, in their efforts to form a thorough and logical system of drawing, they have followed chiefly certain preconceived maxims and principles, and have paid little or no attention to the system which has gradually been formed in the workshops, and which is based upon the actual requirements of the users of drawings and the convenience of the makers of them. Two systems have thus been formed, in many respects similar, but differing materially in some essential points and unfortunately, so it seems to me, the professional teachers of drawing have not in most cases followed the usages of the shops. From this difference between theory and practice has arisen much confusion and many misunderstandings, and more or less expensive mistakes have resulted. Now what I want particularly to say to the students of the Franklin Institute School is that they may rest assured that all that has been taught them is just of the kind which has been found to be of the greatest value in practice, and they will not be called upon to unlearn the lessons of the past year in order to acquire newer or more practical methods. No doubt many of them have discovered that more knowledge is required in drawing than they believed necessary, and perhaps they realize that facility in the use of drawing instruments is at best only one step in learning the art of drawing.

I trust, too, that this discovery will not be discouraging, but will

stimulate all to renewed exertions to perfect themselves in so valuable an art, and also, if possible, to push their inquiries still further into those branches of thought, such as geometry and algebra, which are so intimately connected with mechanical drawing.

CONSERVATION OF SOLAR ENERGY.

By Pliny Earle Chase, LL.D.

Some of the results of photodynamic elasticity, which have been already indicated in the Journal of the Franklin Institute, have acquired new importance from the recent discussions of the views of Dr. C. William Siemens.

If the so-called luminiferous æther is an atmosphere of great elasticity, in considering the influence of solar rotation upon luminous vibrations, regard should be paid to the centrifugal force, not only at Sun's surface, but also at all other distances from the centre of the system, where an appreciable disturbance may be looked for.

Let r_0 represent Sun's semidiameter, then Laplace's limit between rotation and revolution is at $36{\cdot}35 r_0$. The centrifugal force of rotation at that limit is $36{\cdot}35^2$ times as great as at Sun's surface, while the centripetal force of gravitation is only $\frac{1}{1321{\cdot}3}$ as great. The photographs of the solar eclipse to which Dr. Siemens refers (*Nature*, April 20, 1882), unquestionably confirm his views, by indicating an atmospheric oblateness which may be due to the equilibrating tendencies of these two opposing forces.

If the æthereal disturbances which spring from this source are not sufficient to account for luminous and thermal vibrations we may look still further, to the velocity which subsiding particles would acquire in falling from Laplace's equatorial limit to the poles. If there were no resistance, the velocity would be $\left(\frac{35{\cdot}35}{36{\cdot}35} \times 2gr\right)^{\frac{1}{2}} = 376{\cdot}8$ miles per second. Any diminution of this velocity by resistance would be converted into heat. The mean limit between centrifugal and centripetal tendencies being in latitude 30°, the mean diminution of velocity, when the particles have reached the polar zone, is ·982 of 376·8 = 370 miles, representing a mechanical equivalent of 288,670,000,000 J for every pound of subsiding matter. The formula of torsional elasticity

(this journal, cxiii. 437), provides for radiations with the oscillatory velocity of light, and the tendency of nebulæ to a discoid or flattened form thus gains a new meaning.

The spiral descent of the subsiding particles, in their approach to the poles, gives rise to Ampérian currents, which account for Maxwell's identification of luminous and electro-magnetic waves; the axial core of the spirals is the rod of the virtual solar pendulum (*loc. cit.*), of which the length and the radius of torsion are both determined by the solar modulus of light; the continual succession of spiral impulsions converts reciprocal oscillation into uniform rotation; the *precise* accordance between the time of rotary oscillation and the time of acquiring or of losing the velocity of luminous projection, shows the equally precise agreement between centrifugal æthereal action and centripetal gravitating reaction; the combination of axial rotation with orbital revolution induces continual shiftings of inertial resistance, which must be followed by continual renewals of æthereal disturbance; the perpetual maintenance of luminous oscillation by influx, as well as by an equivalent efflux, removes the "reproach of Thermodynamics."

Such are a few of the obvious considerations which are suggested by the identity of luminous and gravitating oscillatory velocity at the centre of the solar system. In subjecting them to the tests of mathematical analysis, the equilibrating tendencies of centrifugal and centripetal action should be specially studied with reference to three oblate spheroids, all of which have the sun's poles for their common poles. Their equatorial loci are respectively coincident with Laplace's limit ($36{\cdot}35r_0$), the virtual radius of solar torsion ($688{\cdot}95r_0$), and the solar modulus of light ($474657r_0$).

Minima of Sun Spots in 1881.—A. Riccot found that the northern solar hemisphere was without spots on 23 days, the southern on 94 days. There were 12 periods of minima on the north, and 18 on the south of the equator. The intervals between the minima did not differ much from a solar synodic rotation. The centres of the minima of the northern hemisphere fall between 241° and 360°; those of the southern hemisphere are found in all longitudes, but with some accumulation between 56° and 70°. These facts show that solar activity is localized for a long time in certain regions of the sun's surface, as Tacchini had previously found.—*Comptes Rendus*, xciv, 1169.

C.

NEW THEORY OF THE SUN—THE CONSERVATION OF SOLAR ENERGY.

By C. William Siemens.

A paper was recently read by me before the Royal Society, under the above title, which may be termed a first attempt to open for the sun a creditor and debtor account, inasmuch as he has hitherto been regarded only as the great almoner, pouring forth incessantly his boundless wealth of heat, without receiving any of it back. Such a proposal touches the root of solar physics, and cannot therefore be expected to pass without challenge—to meet which I gladly embrace the opportunity, now offered to me through the courtesy of the editor of this review, of enlarging somewhat upon the first concise statement of my views regarding this question.

Man has from the very earliest ages looked up with a feeling of awe and wonderment to our great luminary, to whom we owe not only the light of day, but the genial warmth by which we live, by which our hills are clad with verdure, our rivers flow, and without which our life-sustaining food, both vegetable and animal, could not be produced.

When for our comfort and our use we resort to a fire, either of wood or coal, we know now by the light of modern science that we are utilizing only solar rays that have been stored up by the aid of the process of vegetation in our forests or in the forests of former geological ages, when our coal-fields were the scenes of rank tropical growth. The potency of the solar ray in this respect was recognized—even before science had discovered its true significance—by clear-sighted men such as the late George Stephenson, who, when asked what in his opinion was the ultimate cause of the motion of his locomotive engine, said that he thought it went by "the bottled-up rays of the sun."

With the exception of our coal-fields and a few elementary combustible substances, such as sulphur and what are called the precious metals, which we find sparsely scattered about, our earth consists essentially of combined matter. Thus our rivers, lakes, and oceans are filled with oxidized hydrogen, the result of a most powerful combustion; and the crust of our earth is found to consist either of quartz (a combination of the metal silicon with oxygen) or limestone (oxidized

calcium combined with oxidized carbon), or of other metals, such as magnesium, aluminium, or iron, oxidized and combined in a similar manner. Excepting, therefore, the few substances before enumerated, we may look upon our earth, near its surface at any rate, as a huge ball of cinder, which, if left to itself, would soon become intensely cold, and devoid of life or animation of any kind.

It is true that a goodly store of heat still exists in the interior of our earth, which, according to some geologists, is in a state of fusion, and must certainly be in a highly heated condition; but this internal heat would be of no avail, owing to the slow rate of conduction, by which alone, excepting volcanic action, it could be brought to us living upon its surface.

An estimate of the amount of heat poured down annually upon the surface of our earth may be formed from the fact that it exceeds a million times the heat producible by all the coal raised, which may be taken at 280,000,000 tons a year.

If, then, we depend upon solar radiation for our very existence from day to day, it cannot be said that we are only remotely interested in solar physics, and the question whether and how solar energy, comprising the rays of heat, of light, and the actinic rays, is likely to be maintained, is one in which we have at least as great a reversionary interest as we have in landed estate or other property.

If the amount of heat, or, more correctly speaking, of energy, supplied annually to our earth is great as compared with terrestrial quantities, that scattered abroad in all directions by the sun strikes us as something almost beyond conception.

The amount of heat radiated from the sun has been approximately computed by the aid of the pyrheliometer of Pouillet, and by the actinometers of Herschel, at 18,000,000 heat-units from every square foot of its surface per hour; or, expressed popularly, if coal were consumed on the surface of the sun in the most perfect manner, our total annual production of 280,000,000 tons, being the estimated produce of all the coal-mines of the earth, would suffice to keep up solar radiation for only one forty-millionth part of a second; or, if the earth were a mass of coal, and could be supplied by contract to the solar furnacemen, this supply would last them just thirty-six hours.

If the sun were surrounded by a solid sphere of a radius equal to the mean distance of the sun from the earth (95,000,000 miles), the whole of this prodigious amount of heat would be intercepted; but

considering that the earth's apparent diameter, as seen from the sun, is only seventeen seconds, the earth can intercept only the 2250-millionth part. Assuming that the other planetary bodies swell the amount of intercepted heat to ten times this amount, there remains the important fact that $\frac{2249999999}{2250000000}$ of the solar energy is radiated into space, and apparently lost to the solar system, and only $\frac{1}{2250000000}$ utilized or intercepted.

Notwithstanding this enormous loss of heat, solar temperature has not diminished sensibly for centuries, if we neglect the periodic changes, apparently connected with the appearance of sun-spots, that have been observed by Lockyer and others, and the question forces itself upon us, how this great loss can be sustained without producing an observable diminution of solar temperature, even within a human life-time.

Among the ingenious hypotheses intended to account for a continuance of solar heat is that of shrinkage or gradual reduction of the sun's volume, suggested by Helmholtz. It may, however, be argued against this theory that the heat so produced would be liberated throughout its mass, and would have to be brought to the surface by conduction, aided perhaps by convection; but we know of no material of sufficient conductivity to transmit anything approaching the amount of heat lost by radiation.

Chemical action between the constituent parts of the sun has also been suggested; but here again we are met by the difficulty that the products of such combination would, ere this, have accumulated on the surface, and would have formed a barrier against further action.

These difficulties led Sir William Thomson to the suggestion that the cause of maintenance of solar temperature might be found in the circumstance of meteorites, not falling upon the sun from great distances in space, as had been suggested by Mayer and Waterton, but circulating with an acquired velocity within the planetary distances of the sun, and he shows that each pound of matter so imported would represent a large number of heat-units, without disturbing the planetary equilibrium. But in considering more fully the enormous amount of planetary matter that would be required for the maintenance of the solar temperature, Sir William Thomson soon abandoned this hypothesis for that of simple transfer of heat from the interior of a fluid sun to the surface by means of convection-currents, which latter

hypothesis is at the present time supported by Professor Stokes and other leading physicists.

This theory has certainly the advantage of accounting for the greatest possible store of heat within the solar mass, because it supposes the latter to consist in the main of a fluid heated to such a temperature that, if it were relieved at any point of the confining pressure, it would flash into gas of a vastly inferior, but still of an elevated, temperature. It is supposed that such fluid material, or material in the "critical" condition, as Professor Thomas Andrews, of Belfast, has named it, is continually transferred to the surface by means of convection-currents, that is to say, by currents forming naturally when a fluid substance is cooled at its upper snrface, and sinks down after cooling to make room for ascending material at the comparatively higher temperature. It is owing to such convection-currents that the temperature of a room is, generally speaking, higher toward the ceiling than toward the floor, and that upon plunging a thermometer into a tank of heated water the surface temperature is found slightly superior to that near the bottom.

These convection-currents owe their existence to a preponderance of the cooled descending over the ascending current; but this difference being slight, and the ascending and descending currents intermixing freely, they are, generally speaking, of a sluggish character; hence, in all heating apparatus, it is found essential to resort either to artificial propulsion, or to separating walls between the ascending and the descending currents, in order to give effect to the convective transfer of heat.

In the case of a fluid sun another difficulty presents itself through the circumstance that the vast liquid interior is enveloped in a gaseous atmosphere, which, although perhaps some thousands of miles in depth, represents a relatively very small store of heat. Convection-currents may be supposed active in both the gaseous atmosphere and in the fluid ocean below, but the surface of this fluid must necessarily constitute a barrier between the two convective systems, nor could the convective action of the gaseous atmosphere—that is to say, the simple up and down currents caused by surface refrigeration—be such as to disturb the liquid surface below to any great extent, because each descending current would have had plenty of time to get intermixed with its neighboring ascending current, and would, therefore, have reached its least intensity on arriving on the liquid surface.

As regards the liquid, its most favorable condition for heating purposes would be at the critical point, or that at which the slightest diminution of superincumbent pressure would make it flash off into gas; but considering that, by means of conduction and convection, the liquid matter must have assumed, in the course of ages, a practically uniform temperature to a very considerable depth, it follows that the liquid below the surface, with fluid pressure in addition to that of the superimposed gaseous atmosphere, must be ordinary fluid, the critical condition being essentially confined only to the surface.

Conditions analogous to those here contemplated are met with in a high-pressure steam-boiler, with its heated water and dense vapor atmosphere. Suppose the fire below such a boiler be withdrawn, and its roof be exposed to active radiation into space, what should we observe through a strong pane of glass inserted in the side of the boiler near the liquid surface, lit up by an incandescent electric lamp within? The loss of heat by radiation from the boiler would give rise to convection-currents, and partial condensation of the vapor atmosphere; then, if the motion of the water were made visible by means of coloring matter, we should observe convection-currents in the fluid mass separate and distinct from those in the gaseous mass; but these convection-currents would cause no visible disturbance of the liquid surface, which would present itself to the eye with the smoothness of a mirror. It is only in the event of the steam-pressure being suddenly relieved at any point on the surface that a portion of the water would flash into steam, causing a violent upheaval of the liquid.

The dark spots on the sun appear to indicate commotion of this description, but these are evidently not the result of mere convection-currents; if they were, they would occur indiscriminately over the entire surface of the sun, whereas telescopic observation has revealed the fact that they do occur almost exclusively in two belts, between the equator and the polar surfaces on either side. Their occurrence could be satisfactorily explained if we could suppose the existence of strong lateral currents flowing from the polar surfaces toward the equator, which lateral currents in the solar atmosphere would cause cyclones or vortex action with a lower and denser atmosphere, consisting probably of metallic vapors; this vortex action extending downward would relieve the fluid ocean locally from pressure, and give rise to explosive outbursts of enormous magnitude, projecting the lower atmosphere high above the photosphere, with a velocity measured,

according to Lockyer, by a thousand miles a second. It will be seen from what follows how, according to my view, such vortex action in those intermediate regions of the sun would necessarily be produced.

But supposing that, notwithstanding the difficulties just pointed out, convection-currents sufficed to effect a transfer of internal heat to the surface with sufficient rapidity to account for the enormous surface-loss by radiation, we should only have the poor satisfaction of knowing that the available store would last longer than might have been expected, whereas a complete solution of the problem would be furnished by a theory, according to which the radiant energy which is now supposed to be dissipated into space and irrecoverably lost to our solar system, could be arrested and brought back in another form to the sun himself, there to continue the work of solar radiation.

Some six years ago the thought occurred to me that such a solution of the solar problem might not lie beyond the bounds of possibility, and, although I cannot claim intimate acquaintance with the intricacies of solar physics, I have watched its progress, and have engaged also in some physical experiments bearing upon the question, all of which have served to strengthen my confidence, and to ripen in me the determination to submit my views, not without some misgiving, to the touchstone of scientific criticism.

For the purpose of my theory, stellar space is supposed to be filled with highly rarefied gaseous bodies, including hydrogen, oxygen, nitrogen, carbon, and their compounds, besides solid materials in the form of dust. Each planetary body would in that case attract to itself an atmosphere depending for density upon its relative attractive importance, and it would not seem unreasonable to suppose that the heavier and less diffusible gases would form the staple of these local atmospheres; that, in fact, they would consist mostly of nitrogen, oxygen, and carbonic acid, while hydrogen and its compounds would predominate in space.

In support of this view it may be urged that, in following out the molecular theory of gases, as laid down by Clausius, Clerk Maxwell and Thomson, it would be difficult to assign a limit to a gaseous atmosphere in space; and, further, that some writers—among whom I will here mention only Grove, Humboldt, Zöllner and Mattieu Williams—have boldly asserted the existence of a space filled with matter. But Newton himself, as Dr. Sterry Hunt tells us in an interesting paper

which has only just reached me, has expressed views in favor of such an assumption.

The history of Newton's paper is remarkable and very suggestive. It was read before the Royal Society on the 9th and 16th of December, 1675, and remained unpublished until 1757, when it was printed by Birch, the then secretary, in the third volume of his "History of the Royal Society," but received no attention; in 1846 it was published in the "Philosophical Magazine" at the suggestion of Harcourt, but was again disregarded; and now, once more, only a few months since, a philosopher on the other side of the Atlantic brings back to the birthplace of Newton his forgotten and almost despised work of two hundred years ago.

Quoting from Dr. Sterry Hunt's paper:

"Newton in his Hypothesis imagines 'an ethereal medium much of the same constitution with air, but far rarer, subtler, and more elastic. . . . . But it is not to be supposed that this medium is one uniform matter, but composed partly of the main phlegmatic body of ether, partly of other various ethereal spirits, much after the manner that air is compounded of the phlegmatic body of air intermixed with various vapors and exhalations.' Newton further suggests in his Hypothesis that this complex spirit or ether, which, by its elasticity, is extended throughout all space, is in continual movement and interchange. 'For Nature is a perpetual circulatory worker, generating fluids out of solids, and solids out of fluids; fixed things out of volatile, and volatile out fixed; subtile out of gross, and gross out of subtile; some things to ascend and make the upper terrestrial juices, rivers, and the atmosphere, and by consequence others to descend for a requital to the former. And as the earth, so perhaps may the sun imbibe this spirit copiously, to conserve his shining, and keep the planets from receding further from him; and they that will may also suppose that this spirit affords or carries with it thither the solary fuel and material principle of life, and that the vast ethereal spaces between us and the stars are for a sufficient repository for this food of the sun and planets. . . . Thus, perhaps, may all things be originated from ether."

If at the time of Newton chemistry had been understood as it now is, and if, moreover, he had been armed with that most wonderful of all modern scientific instruments, the spectroscope, the direct outcome of his own prismatic analysis, there appears to be no doubt that the author of the laws of gravitation would have so developed his thoughts

upon solar fuel that they would have taken the form rather of a scientific discovery than of a mere speculation.

Our proof that interstellar space is filled with attenuated matter does not rest, however, solely upon the uncertain ground of speculation. We receive occasionally upon our earth celestial visitors termed meteorites; these are known to travel in loose masses round the sun in orbits intersecting at certain points that of our earth. When in their transit they pass through the denser portion of our atmosphere they become incandescent, and are popularly known as falling stars. In some cases they are really deserving of that name, because they strike down upon our earth, from the surface of which they have been picked up and subjected to searching examination while still warm after their exertion. Dr. Flight has only very recently communicated to the Royal Society an analysis of the occluded gases of one of these meteorites as follows:

CO_2 (Carbonic acid), ...	0·12
CO (Carbonic oxide), ...	31·88
H (Hydrogen), ...	45·79
CH_4 (Marsh-gas), ...	4·55
N (Nitrogen), ...	17·66
	100·00

It appears surprising that there was no aqueous vapor, considering that there was much hydrogen and oxygen in combination with carbon; but perhaps the vapor escaped observation, or was expelled to a greater extent than the other gases by external heat when the meteorite passed through our atmosphere. Opinions concur that the gases found occluded in meteorites cannot be supposed to have entered into their composition during their very short period of traversing our denser atmosphere; but, if any doubt should exist on this head, it ought to be set at rest by the fact that the gas principally occluded is hydrogen, which is not contained in our atmosphere in any appreciable quantity.

Further proof of the fact that stellar space is filled with gaseous matter is furnished by spectrum analysis, and it appears from recent investigation, by Dr. Huggins and others, that the nucleus of a comet contains very much the same gases found occluded in meteorites, including "carbon, hydrogen, nitrogen, and probably oxygen," while,

according to the views set forth by Dewar and Liveing, it also contains nitrogenous compounds, such as cyanogen.

Adversely to the assumption that interplanetary space is filled with gases, it is urged that the presence of ordinary matter would cause sensible retardation of planetary motion, such as must have made itself felt before this; but, assuming that the matter filling space is an almost perfect fluid, not limited by border surfaces, it can be shown on purely mechanical grounds that the retardation by friction through such an attenuated medium would be very slight indeed, even at planetary velocities.

But it may be contended that, if the views here advocated regarding the distribution of gases were true, the sun should draw to himself the bulk of the least diffusible, and therefore the heaviest gases, such as carbonic acid, carbonic oxide, oxygen and nitrogen, whereas spectrum analysis has proved, on the contrary, a great prevalence of hydrogen.

In explanation of this seeming anomaly, it can be shown, in the first place, that the temperature of the sun is so high that such compound gases as carbonic acid and carbonic oxide could not exist within him, their point of dissociation being very much below the solar temperature. It has been contended, indeed, by Mr. Lockyer, that none of the metalloids have any existence at these temperatures, although as regards oxygen Dr. Draper asserts its existence in the solar photosphere. There must be regions, however, outside that thermal limit, where their existence would not be jeopardized by heat; and here great accumulation of the comparatively heavy gases that constitute our atmosphere would probably take place, were it not for a certain counterbalancing action.

I here approach a point of primary importance in my argument, upon the proof of which my further conclusions must depend.

The sun completes one revolution on its axis in twenty-five days, and its diameter being taken at 882,000 miles, it follows that the tangential velocity amounts to 1·25 miles per second, or to what the tangentical velocity of our earth would be if it occupied five hours instead of twenty-four in accomplishing one revolution. This high rotative velocity of the sun must cause an equatorial rise of the solar atmosphere, to which Mairan, in 1731, attributed the appearance of zodiacal light. Laplace rejected this explanation on the ground that zodiacal light extended to a distance from the sun exceeding our own,

whereas the equatorial rise of the solar atmosphere due to its rotation could not exceed nine-twentieths of the distance of Mercury. But it must be remembered that Laplace based his calculation upon the generally accepted hypothesis of an empty stellar space (occupied only by an imaginary ether), and it can be shown that the result of solar rotation would be widely different, if supposed to take place within a medium of unbounded extension. In this case pressures would be balanced all round, and the sun would act mechanically upon the floating matter surrounding him in the manner of a fan, drawing it toward himself upon the polar surfaces, and projecting it outward in a continuous disk-like stream from the equatorial surfaces.

By this fan action, hydrogen, hydrocarbons, and oxygen are supposed to be drawn in enormous quantities toward the polar surfaces of the sun; during the gradual approach they pass from their condition of extreme attenuation and intense cold to that of compression, accompanied with increase of temperature, until, on approaching the photosphere, they burst into flame, giving rise to a great development of heat, and a temperature commensurate with their point of dissociation at the solar density. The result of their combustion will be aqueous vapor and carbonic acid, and these products of combustion, in yielding to the influence of centrifugal force, will flow toward the solar equator, and be thence projected into space.

In view of the importance of this centrifugal action for the purpose of my theory, the following simple mathematical statement of the problem may not be thought out of place: Let us consider the condition of two equal gaseous masses, at equal distances from the solar center, the one in the direction of the equator, the other in that of either of the poles. These two masses would be equally attracted toward the sun, and balance one another as regards the force of gravitation, but the former would be subject to another force, that of centrifugal action, which, however small in amount as compared with the enormous attraction of the sun, would destroy the balance, and determine a motion toward the sun as regards the mass opposite the polar surface, and into space as regards the equatorial mass. The same action would take effect upon the masses filling their places, and the result must be a continuous current depending for its velocity upon the rate of solar rotation. The equatorial current so produced, owing to its mighty proportions, would flow outward into space, to a practically unlimited distance.

The next question for consideration is, What would become of these products of combustion when thus returned into space? Apparently they would gradually change the condition of stellar material, rendering it more and more neutral; but I venture to suggest that the possibility, nay, the probability, that solar radiation will, under these conditions, step in to bring back the combined materials to a state of separation by dissociation carried into effect at the expense of that solar energy which is now supposed to be irrevocably lost or dissipated into space, as the phrase goes.

According to the law of dissociation as developed by Bunsen and Sainte-Claire Deville, the point of decomposition of different compounds depends upon the temperature on the one hand, and upon the pressure on the other. According to Sainte-Claire Deville, the dissociation tension of aqueous vapor at atmospheric pressure and at 2,800°C. is 0·5, that is to say one-half of the vapor would exist as such, the remaining half being found as a mechanical mixture of hydrogen and oxygen; but, with the pressure, the temperature of dissociation rises and falls, as the temperature of saturated steam rises and falls with its pressure. It is therefore conceivable that the solar photosphere may be raised by combustion to a temperature exceeding 2,800°C., whereas dissociation may be effected in space at a lower temperature. This temperature of 2,800° would be quite sufficient to account for the character and amount of solar radiation, if it is only borne in mind that the luminous atmosphere may be a thousand miles in depth, and that the flame of hydrogen and hydrocarbons, in the uppermost layers of this zone, is transparent to the radiant energy produced in the layers below, thus making the total radiation rather the sum of matter in combustion than the effect of a very intensely heated surface.

Sainte-Claire Deville's investigations had reference only to heats measured by means of pyrometers, but do not extend to the effects of radiant heat. Dr. Tyndall has shown by his important researches that vapor of water and other gaseous compounds intercept radiant heat in a most remarkable degree, and there is other evidence to show that radiant energy from a source of high intensity possesses a dissociating power far surpassing the measurable temperature to which the compound substance under its influence is raised. Thus carbonic acid and water are dissociated in the leaf-cells of plants under the influence of the direct solar ray at ordinary summer temperature, and experi-

ments in which I have been engaged for nearly three years* go to prove that this dissociating action is obtained also under the radiant influence of the electric arc, although it is scarcely perceptible if the energy is such as can be produced by an inferior source of heat.

The point of dissociation of aqueous vapor and carbonic acid admits, however, of being determined by direct experiment. It engaged my attention some years ago, but I have hesitated to publish the qualitative results I then obtained, in the hope of attaining to quantitative proofs.

These experiments consisted in the employment of glass tubes furnished with platinum electrodes, and filled with aqueous vapor or with carbonic acid in the usual manner, the latter being furnished with caustic soda to regulate the vapor-pressure by heating. Upon immersing one end of the tube charged with aqueous vapor in a refrigerating mixture of ice and chloride of calcium, its temperature at that end was reduced to —32°C., corresponding to a vapor-pressure, according to Regnault, of $\frac{1}{1800}$ of an atmosphere. When so cooled no slow electric discharge took place on connecting the two electrodes with a small induction-coil. I then exposed the end of the tube projecting out of the freezing mixture, backed by white paper, to solar radiation (on a clear summer's day) for several hours, when, upon again connecting up to the inductorium, a discharge, apparently that of a hydrogen vacuum, was obtained. This experiment being repeated furnished unmistakable evidence, I thought, that aqueous vapor had been dissociated by exposure to solar radiation. The carbonic-acid tubes gave, however, less unmistakable effects. Not satisfied with these qualitative results, I made arrangements to collect the permanent gases so produced by means of a Sprengel pump, but was prevented by lack of time from pursuing the inquiry, which I propose, however, to resume shortly, being of opinion that, independently of our present speculation, the experiments may prove useful in extending our knowledge regarding the laws of dissociation.

It should be here observed that, according to Professor Stokes, the ultra-violet rays are in large measure absorbed in passing through clear glass, and it follows from this discovery that only a small portion of the chemical rays found their way through the tubes to accomplish the

* See *Proceedings Royal Society*, vol. xxx, March 1, 1880; also a paper read before Section A of the British Association, September 1, 1881, and ordered to be printed in the report.

work of dissociation. This circumstance being adverse to the experiment only serves to increase the value of the effect observed, while it appears to furnish additional proof of the fact, first enunciated by Professor Draper, and corroborated by my own experiments on plants, that the dissociating power of light is not confined to the ultra-violet rays, but depends in the process of vegetation chiefly upon the yellow and red rays.

Assuming, for my present purpose, that dissociation of aqueous vapor was really effected in the experiment just described, and assuming, further, that stellar space is filled with aqueous and other vapors of a density not exceeding the $\frac{1}{2000}$ part of our atmosphere, it seems reasonable to suppose that its dissociation would be effected by solar radiation, and that solar energy would thus be utilized. The conjoint presence of aqueous vapor, carbonic acid and nitrogen would only serve to facilitate their decomposition, in consequence of the simultaneous formation of hydrocarbons and nitrogenous compounds by combination of the nascent hydrogen and the nitrogen with carbon in a manner analogous to what occurs in vegetation. It is not necessary to suppose that all the energy radiated from the sun into space should be intercepted, inasmuch as even a partial return of heat in the manner described would serve to supplement solar radiation, the balance being made up by absolute loss. To this loss of energy would have to be added that consumed in sustaining the circulating current, which, however, need not relatively be more than what is known to be lost on our earth through the tidal action, and may be supposed to be compensated as regards the time of solar rotation by gradual shrinkage.

By means of the fan-like action resulting from the rotation of the sun, the vapors dissociated in space to-day would be drawn toward the polar surfaces of the sun to-morrow, be heated by increase in density, and would burst into flame at a point where both their density and temperature had reached the necessary elevation to induce combustion, each complete cycle taking, however, years to be accomplished. The resulting aqueous vapor, carbonic acid and carbonic oxide would be drawn toward the equatorial regions, and be then again projected into space by centrifugal force.

Space would, according to these views, be filled with gaseous compounds in process of decomposition by solar radiant energy, and the existence of these gases would furnish an explanation of the solar

absorption spectrum, in which the lines of some of the substances may be entirely neutralized and lost to observation. As regards the heavy metallic vapors revealed in the sun by the spectroscope, it is assumed that these form a lower and denser solar atmosphere, not participating in the fan-like action which is supposed to affect the light outer atmosphere only, in which hydrogen is the principal factor.

Such a dense metallic atmosphere could not participate in the fan action affecting the lighter photosphere, because this is only feasible on the supposition that the density of the inflowing current is, at equal distances from the gravitating centre, equal or nearly equal to the outflowing current. It is true that the products of combustion of hydrogen and hydrocarbon are denser than their constituents, but this difference may be balanced by their superior temperature on leaving the sun, whereas the metallic vapors would be unbalanced, and would therefore obey the laws of gravitation, recalling them to the sun. On the surface of contact between the two solar atmospheres, intermixture induced by friction must take place, however, giving rise to those vortices and explosive effects within the zones of the sun, between the equator and the polar surfaces, to which reference has already been made in this article; these may appropriately be called the "stormy regions" of the sun, which were first observed and commented upon by Sir John Herschel. Some of the denser vapors would probably get intermixed, be carried away mechanically by the lighter gases, and give rise to that cosmic dust observed to fall upon our earth in not inappreciable quantities, and generally assumed hitherto to be the *débris* of broken meteorolites. Excessive intermixture between the heat-producing atmosphere and the metallic vapors below appears to be prevented by the existence of an intermediate neutral atmosphere, and called the penumbra.

As the whole solar system moves through space at a pace estimated at 150,000,000 miles annually (being about one-fourth of the velocity of the earth in its orbit), it appears possible that the condition of the gaseous fuel supplying the sun may vary according to its state of previous decomposition, in which other heavenly bodies may have taken part, and whereby an interesting reflex action between our sun and other heavenly bodies would be brought about. May it not be owing to such differences in the quality of the fuel supplied that the observed variations of the solar heat may arise?—and may it not be in consequence of such changes in the thermal condition of the photo-

sphere that the extraordinary convulsions revealed to us as sun-spots occur?

The views here advocated could not be thought acceptable unless they furnish at any rate a consistent explanation of the still somewhat mysterious phenomena of the zodiacal light and of comets. Regarding the former, we should be able to revert to Mairan's views, the objection by Laplace being met by a continuous outward flow from the solar equator. Luminosity would be attributable to particles of dust emitting light reflected from the sun, or to phosphorescence. But there is another cause for luminosity of these particles, which may deserve serious consideration. Each particle would be electrified by gaseous friction in its acceleration, and its electric tension would be vastly increased in its forcible removal, in the same way as the fine dust of the desert has been observed by Dr. Werner Siemens to be in a state of high electrification on the apex of the Cheops Pyramid. Could not the zodiacal light also be attributed to slow electric discharge backward from the dust toward the sun?—and would not the same cause account for a great difference of potential between the sun and earth, which latter may be supposed to be washed by the solar radial current? May not the presence of the radial solar current also furnish us with an explanation of the fact that hydrogen, while abounding apparently in space, is practically absent in our atmosphere, where aqueous vapor and carbonic acid, which would come to us directly from the sun, take its place? An action analogous to this, though on a much smaller scale, may be set up also by terrestrial rotation, giving rise to an electrical discharge from the outgoing equatorial stream to the polar regions, where the atmosphere to be pierced by the return flood is of least resistance. Thus the phenomenon of the aurora borealis or northern lights would find an easy explanation.

The effect of this continuous outpour of solar materials could not be without very important influences as regards the geological conditions of our earth. Geologists have long acknowledged the difficulty of accounting for the amount of carbonic acid that must have been in our atmosphere, at one time or another, in order to form with lime those enormous beds of dolomite and limestone, of which the crust of our earth is in great measure composed. It has been calculated that, if this carbonic acid had been at one and the same time in our atmosphere, it would have caused an elastic pressure fifty times that of our present atmosphere; and, if we add the carbonic acid that

must have been absorbed in vegetation in order to form our coal-beds, we should probably have to double that pressure. Animal life, of which we find abundant traces in these "measures," could not have existed under such conditions, and we are almost forced to the conclusion that the carbonic acid must have been derived from an external source.

It appears to me that the theory here advocated furnishes a feasible solution of this geographical difficulty. Our earth being situated in the outflowing current of the solar products of combustion, or, as it were, in the solar chimney, would be fed from day to day with its quota of carbonic acid, of which our local atmosphere would assimilate as much as would be necessary to maintain it in a carbonic-acid vapor density balancing that of the solar current; we should thus receive our daily supply of this important constituent (with the regularity of fresh rolls for breakfast), which, according to an investigation by M. Reiset, communicated to the French Academy of Sciences by M. Dumas on the 6th of March last, amounts to the constant factor of one ten-thousandth part of our atmosphere. The aqueous vapor in the air would be similarly maintained as to its density, and its influx to, or reflux from, our atmosphere would be determined by the surface temperature of our earth.

It is also important to show how the phenomena of comets could be harmonized with the views here advocated, and I venture to hope that these occasional visitors will serve to furnish us with positive evidence in my favor. Astronomical physicists tell us that the nucleus of a comet consists of an aggregation of stones similar to meteorites. Adopting this view, and assuming that the stones have absorbed in stellar space gases to the amount of six times their volume, taken at atmospheric pressure, what, it may be asked, will be the effect of such a divided mass advancing toward the sun at a velocity reaching in perihelion the prodigious rate of 366 miles per second (as observed in the comet of 1845), being twenty-three times our orbital rote of motion? It appears evident that the entry of such a mass into a comparatively dense atmosphere must be accompanied by a rise of temperature by frictional resistance, aided by attractive condensation. At a certain point the increase of temperature must cause ignition, and the heat thus produced must drive out the occluded gases, which in an atmosphere 3,000 times less dense than that of our earth would produce $6 \times 3{,}000 = 10{,}000$ times the volume of the stones themselves.

These gases would issue forth in all directions, but would remain unobserved except in that of motion, in which they would meet the interplanetary atmosphere with the compound velocity, and form a zone of intense combustion, such as Dr. Huggins has lately observed to surround the one side of the nucleus, evidently the side of forward motion. The nucleus would thus emit original light, whereas the tail may be supposed to consist of stellar dust rendered luminous by reflex action produced by the light of the sun and comet combined, as foreshadowed already by Tyndall, Tait, and others, starting each from different assumptions.

Although I cannot pretend to an intimate acquaintance with the more intricate phenomena of solar physics, I have long had a conviction, derived principally from familiarity with some of the terrestrial effects of heat, that the prodigious dissipation of solar heat is unnecessary to satisfy accepted principles regarding the conservation of energy, but that solar heat may be arrested and returned over and over again to the sun, in a manner somewhat analogous to the action of the heat recuperator in the regenerative engine and gas-furnace. The fundamental conditions are:

1. That aqueous vapor and carbon compounds are present in stellar or interplanetary space.

2. That these gaseous compounds are capable of being dissociated by radiant solar energy while in a state of extreme attenuation.

3. That the vapors so dissociated are drawn toward the sun in consequence of solar rotation, are flashed into flame in the photosphere, and rendered back into space in the condition of products of combustion.

Three weeks have now elapsed since I ventured to submit these propositions to the Royal Society for scientific criticism, and it will probably interest my readers to know what has been the nature of that criticism and the weight of additional evidence for or against my theory.

Criticism has been pronounced by mathematicians and physicists, but affecting singularly enough the chemical and not the mathematical portion of my argument; whereas chemists have expressed doubts regarding my mathematics while accepting the chemistry involved in my reasoning.

Doubts have been expressed as to the sufficiency of the proof that dissociation of attenuated aqueous vapor and carbonic acid is really

effected by radiant solar energy, and, if so effected, whether the amount of heat so supplied to the sun could be at all adequate in amount to keep up the known rate of radiation. It was admitted in my paper that my own experiments on the dissociation of vapors within vacuous tubes amounted to inferential rather than absolute proof; but the amount of inferential evidence in favor of my views has been very much strengthened since by chemical evidence received from various sources; and I will here only refer to one of these.

Professor Piazzi Smyth, the Astronomer Royal for Scotland, has, in connection with Professor Herschel, of Newcastle, recently presented an elaborate paper or series of papers to the Royal Society of Edinburgh "On the Gaseous Spectra in Vacuum-Tubes," of which he has kindly forwarded me a copy. It appears from these memoirs that when vacuum-tubes, which contain attenuated vapors, have been laid aside for a length of time, they turn practically into hydrogen-tubes. In another very recent paper presented to the Royal Society of Edinburgh, Professor Piazzi Smyth furnishes important additional proof of the presence of oxygen in the outer solar atmosphere, and gives an explanation why this important element has escaped observation by the spectroscope. Additional proof of the existence of oxygen in the outer solar atmosphere has been given by Professor Stoney, the Astronomer Royal for Ireland, and by Mr. R. Meldola in an interesting paper communicated by him to the "Philosophical Magazine," in June, 1878.

As regards the sufficiency of an inflowing stream of dissociated vapors to maintain solar energy, the following simple calculation may be of service: Let it be assumed that the stream flowing in upon the polar surfaces of the sun flashes into flame when it has attained the density of our atmosphere, that its velocity at that time is 100 feet per second (the velocity of a strong terrestrial wind), and that in its composition only one twentieth part is hydrogen and marsh-gas in equal proportions, the other nineteen twentieths being made up of oxygen, nitrogen and neutral compounds. It is well known that each pound of hydrogen develops in burning about 60,000 heat-units, and each pound of marsh-gas about 24,000; the average of the two gases mixed in equal proportion would yield, roughly speaking, 42,000 units; but, considering that only one-twentieth part of the inflowing current is assumed to consist of such combustible matter, the amount of heat developed per pound of inflowing current would be only 2100 heat-

units. One hundred cubic feet, weighing eight pounds, would enter into combustion every second upon each square foot of the polar surface, and would yield $8 \times 60 \times 60 \times 2{,}100 = 60{,}480{,}000$ heat units per hour. Assuming that one-third of the entire solar surface may be regarded as polar heat-receiving surface, this would give 20,000,000 heat-units per square foot of solar surface; whereas, according to Herschel's and Pouillet's measurements, only 18,000,000 heat-units per square foot of solar surface are radiated away. There would thus be no difficulty in accounting for the maintenance of solar energy from the supposed source of supply. On the other hand, I wish to guard myself against the assumption that appears to have been made by some critics, that what I have advocated would amount to the counterpart of "perpetual motion," and therefore to an absurdity. The sun cannot of course get back any heat radiated by himself which has been turned to a purpose; thus the solar heat spent upon our earth in effecting vegetation must be absolutely lost to him.

My paper presented to the Royal Society was accompanied by a diagram of ideal corona, representing an accumulation of igneous matter upon the solar surfaces, surrounded by disturbed regions pierced by occasional vortices and outbursts of metallic vapors, and culminating in two outward streams projecting from the equatorial surfaces into space through many thousands of miles. The only supporting evidence in favor of this diagram were certain indications that may be found in the instructive volume on the sun by Mr. R. A. Proctor. It was therefore a matter of great satisfaction to me to be informed, as I have been by an excellent authority and eye-witness, that my imaginary diagram bore a very close resemblance to the corona observed in America on the occasion of the total eclipse of the sun on the 11th of January, 1880.

Enough has been said, I think, to prove that the theory I have ventured to put forward is the result, at any rate, of considerable reflection; and I may add that, since its first announcement, I have not seen reason to reject any of the links of my chain of argument: these I have here endeavored to strengthen only by additional facts and explanations.

Miracle at the Bar of Science.—In the preface to the fifth volume of *Les Splendeurs de la Foi* Abbe Moigno recounts the several steps of the Roman Catholic church in arriving at the canonization of St. Benoit-Joseph Labre. The preliminary investigation began June 6, 1783, and ended September 22, 1785. The records of this investigation cover 3300 pages. Subsequent examinations occurred at various periods, and the canonization was finally completed on April 16, 1875. Pope Leo XIII has authorized the venerable Abbe to embody an account of the entire process in a volume of his series, and the attention of physicians and other scientific men is invited to the evidence which is presented, and the care which was taken at every step to avoid the possibility of deception.—*Les Mondes*, Supplement, April 29, 1882. C.

Subterranean Tide.—Chase's views, with regard to the influence of electricity upon tidal phenomena (*Proc. Amer. Phil. Soc.*, vol. ix) have been confirmed by late investigations of M. C. Lagrange. In a communication to *Ciel et Terre* he says: "Whatever resistance may be opposed by a body to distortion, when it is influenced by certain forces, the resistance is not infinite, and the most tenacious bodies undergo in these circumstances a change in their dimensions; moreover, these variations of dimensions are proportional to the dimensions themselves. Hence it happens that bodies of a considerable volume may undergo appreciable distortions, however slight may be their extensions or compressions for a unit of length." Chase has shown (*Proc. Amer. Phil. Soc.*, April 21, 1882, note 217) that all the tidal tendencies which are due to solar and lunar action may be satisfied by a change in the distance between any two molecular centres which is less than $\frac{1}{4000000}$ of their mean distance. F. W. Klonne has studied the tidal movements of the subterranean waters which invaded the mines of Dux, in Bohemia, in the year 1879. Guilio Grablowitz, who has been long engaged in tidal investigations, and who has especially investigated the tidal anomalies of the Adriatic, has discussed the observations of M. Klonne, and finds that while they are influenced by the sun and moon, that influence is mainly exerted upon the solid portions of the globe. Lagrange quotes largely from the memoir of Grablowitz, gives some comparative tables and suggestions, which seem likely to lead to important modifications of tidal theories.—*Ann. de Chim. et de Phys.*, April, 1882. C.

A New Variety of Glass.—The *Wiener Gewerbe-Zeitung* states that a chemist of Vienna has invented a new kind of glass, which contains no silex, potash, soda, lime, nor borax. In appearance it is equal to the common crystal, but more brilliant; it is perfectly transparent, white and clear, and can be cut and polished. It is completely insoluble in water and is not attacked by fluoric acid, but it can be corroded by hydrochloric and nitric acid. When in a state of fusion it adheres to iron, bronze and zinc.—*Gaceta Industrial.* C.

Improvement in Grain Elevators.—The port of Bordeaux, like those of Havre and Marseilles, is to be provided with boat elevators for mechanically unloading grain vessels. The steam motor is replaced by an electric motor. This change allows the boats to be employed during the day for unloading grain, while during the night they are changed into lighthouses, for produciag a powerful electric illumination of the harbor. These movable electric lighthouses will also serve, during the approaching exposition, for the nautical festivals upon the river at night.—*La Lumière Electrique*, vi, 359. C.

Electric Transmission of Power.—J. Chrétien states that the first attempt to transmit motive power by electricity was made in 1873, at the Vienna Exposition, by H. Fontaine. In 1876, at Philadelphia, and in 1878, at Paris, the experiment was repeated. Patents were afterward taken out by Chrétien and by Felix for the application of this mode of transmission to cranes and hoisting apparatus. Important experiments upon ploughing by electricity were made at Sermaize, early in 1879, and since that period great progress has been made in pumping, pile-driving, punching, sawing, sewing, embroidering, weaving, printing, etc. He thinks that it is safe to calculate upon the transmission of 50 per cent. of the whole power. Falls and water-courses, when properly regulated, would allow the utilization of a considerable motive force, at the same time that they favored irrigation and diminished the probability of disastrous freshets. Tides and windmills, in spite of the intermittence of their labor, may be advantageously used through the help of accumulators. Solar heat, when transformed into electrteity, seems to offer a more desirable solution than the direct application to the production of steam. Coal can be more profitably employed under large boilers, which supply powerful and well-perfected motors, at a moderate rate of consumption, than under smaller boilers, which consume from five to thirty times as much fuel per horse-power.—*Soc. des Ecoles d'Arts et Mét.* C.

Franklin Institute.

HALL OF THE INSTITUTE, May 24, 1882.

A special meetiing of the Institute was held this evening at 8 o'clock, to consider the subject of pending legislation in Congress affecting property in patents.

There were present 72 members and 4 visitors.

In the absence of the President and Vice Presidents, Mr. Hector Orr was called upon to act as President *pro tem.*

The Secretary then read the following official order for the meeting, viz.:

HALL OF THE FRANKLIN INSTITUTE, May 19, 1882.

A special meeting of the Institute will be held on Wednesday evening, 24th inst., at 8 o'clock, to take into consideration the subject embraced in the following application addressed to the President.

"*Philadelphia*, May 18, 1882.

"DEAR SIR:—The undersigned members of the Franklin Institute respectfully request the calling of a special meeting of the Institute, to be held on next Wednesday evening, 24th inst., to give expression of its views on the proposition now pending before Congress, to amend the patent laws in the manner set forth in the bill passed by the House of Representatives on Monday, 15th inst.

"Very respectfully,

"H. R. HEYL,	WM. L. DUBOIS,
"HECTOR ORR,	J. E. SHAW,
"LEWIS H. SPELLIER,	JOHN A. WIEDERSHEIM,
"CHAS. E. RONALDSON,	C. HENRY RONEY,
"WM. B. COOPER,	RAPER HOSKINS,
"G. MORGAN ELDRIDGE,	LEWIS S. WARE."

In obedience to Article XII of the by-laws.

W. P. TATHAM, *President.*

The following is the text of the bill referred to, viz.:

"An Act to amend section forty-nine hundred and nineteen of the Revised Statutes, relating to the recovery of damages for the infringement of patents.

"Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That no action for damages or proceeding in equity shall be sustained, nor shall the party be held liable under sections 4919 and 4921 of the Revised Statutes of the United States, for the use of any patented article or device, when it shall appear on the trial that the defendant in such action or proceeding purchased said article for a valuable consideration in the open market."

The President *pro tem.* called attention to a copy of bill printed in large characters and suspended in the Hall for convenience of reference, and invited a free and full expression of opinion preparatory to taking definite action in relation to it.

The subject was thereupon discussed in all its bearings *pro* and *con.*, by the following gentlemen, namely: Thomas Shaw, Geo. R. Moore, Wm. B. Cooper, Prof. E. J. Houston, Amos Stevens, C. F. Reed, Cyrus Phillips, A. de Beaumont, C. H. Chormann, J. E. Mitchell, Henry R. Heyl, and G. Morgan Eldridge, the prevailing sentiment among the speakers being that of strong opposition to the proposed amendment to the patent laws.

At the close of the discussion Mr. Heyl moved that a committee of three be appointed by the Chair to express the sense of the meeting on the subject. The motion was carried, and the following members were named to constitute the committee, viz.: H. R. Heyl, Thos. Shaw and G. M. Eldridge.

The committee, after a brief deliberation, presented the following preamble and resolutions, viz.:

"WHEREAS, By the vote of the House of Representatives of the United States, taken on the 15th day of May, 1882, a bill was passed to amend the United States Patent Laws—which amendment takes away almost the entire protection granted by letters patent to property acquired by invention, and in effect legalizes theft; and

"WHEREAS, It is manifest that any such enactment as will relieve the possessor of a fraudulently made article from all liability as a party to the infringement, will render the protection heretofore guaranteed by letters patent as utterly inadequate as though no patent existed; and

"WHEREAS, The unparalleled advances that have been made by this nation in every department of science and industry are due solely and unquestionably to the wise provisions of our patent laws, and all

legislation that in any degree detracts from the protection now afforded to inventors would paralyze all the industries which by protected ingenuity have become monuments to American progress, and sources of incalculable wealth to the nation;

"*Resolved*, That it is the sense of the Franklin Institute, of the State of Pennsylvania, for the Promotion of the Mechanic Arts,

"That the amendment to section 4919 of the Revised Statues, relating to the recovery of damages for the infringement of patents, which passed the House of Representatives May 15th, 1882:

"Is a violation of the rights ensured to the holders of patents under the laws of the United States;

"Is a deprivation of the remedies which are essential to the maintenance of those rights;

"Is a breach of the contract with patentees made by the laws relating to patents;

"Is injurious to the interests of inventors and patentees, with no compensating advantages to any other honest persons;

"And is destructive of the system of patents in the United States, which has done more than any other one thing for the promotion of the mechanic arts and the advancement of the material interests of the country."

On motion of Mr. Chormann, the preamble and resolutions were adopted.

On motion of Mr. Addison B. Burk, it was resolved that a committee of three be appointed to proceed to Washington, at the proper time, to lay the resolutions before the Senate Committee on Patents, and to represent the sentiment of the meeting. The Chair named the following members to serve on the committee, viz.: Messrs. Thomas Shaw, Prof. Houston and G. M. Eldridge.

It was further resolved, on motion of Mr. J. E. Mitchell, that the preamble and resolutions just passed be printed, and that a copy be sent at the earliest moment to each Senator and Representative in Congress.

Finally, it was decided, on motion of Mr. Eldridge, that the officers of the Institute be instructed to send an officially certified copy of the preamble and resolutions to the President of the Senate and to the Speaker of the House of Representatives.

On motion, adjourned.

WILLIAM H. WAHL, *Secretary*.

JOURNAL

OF THE

FRANKLIN INSTITUTE.

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXIV. AUGUST, 1882. No. 2.

ON A THEOREM OF RANKINE RELATING TO THE ECONOMY OF SINGLE ACTING EXPANSION ENGINES, FIRST PUBLISHED IN 1851.

By PROFESSOR W. P. TROWBRIDGE.

[Read (by title) at the meeting of the American Society Mechanical Engineers, at Philadelphia.]

The object of the theorem above referred to was, in the words of the author, "to investigate and explain the method of determining the rate of expansion, and consequently the dimensions and proportions of a Cornish engine which, with a given maximum pressure of steam in the cylinder, at a given velocity, shall perform a given amount of work at the least possible pecuniary cost, taking into account the expense of fuel and the interest of capital required for the construction."

He further states, as a fundamental proposition, that "by increasing the ratio of expansion in a Cornish engine the quantity of steam required to perform a given duty is diminished and the cost of fuel and of the boilers is lowered. But, at the same time, as the cylinders and every part of the engine must be made larger to admit of greater expansion the cost of the engine is increased."

"It thus becomes a problem of maxima and minima to determine what ratio of expansion ought to be adopted, under given circumstances, in order that the sum of the actual cost of fuel and interest of the capital employed in construction may be the least possible as compared with the work done."

It is somewhat remarkable that this theorem is nowhere alluded to in the author's subsequent elaborate treatise on the steam engine; while on the other hand he was the first to formulate in that treatise, definitely, the true theory of the efficiency of the steam in the cylinder of an engine, and to explain how the combined efficiencies of the boiler, engine and mechanism are to be ascertained from a purely mechanical and theoretical point of view. During the thirty years that have elapsed since the publication of the theorem, its value or importance, if either can be attached to it, have been ignored not only by all eminent writers on the steam engine, but by those most interested, the designers and users of steam engines.

It is reasonable to suppose, from these circumstances, either that there is an inherent fallacy in the theorem itself, or that engineers and business men have found it to be, even if true as a mathematical proposition, inapplicable in designing engines, or in using them.

An apology ought to be offered for asking the further time and attention of this Society to a subject upon which there can be very little difference of opinion among well informed engineers, as far as its theoretical aspects are concerned; but in the recent renewal of the discussion, upon the basis of this old theorem of Rankine, such positive grounds are taken in regard to the necessity of a radical change of views and of practice among engineers concerning the proper method of ascertaining the conditions of maximum economy in the application of steam-power, that a thorough criticism of the new methods seems to be called for. In order to do this it is necessary to enunciate the theorem in its mathematical form.

Let p_e represent the mean effective pressure in the cylinder of an engine per square foot of piston, and V_2 the volume in cubic feet generated by the piston in one hour; then $p_e V_2$ will represent in foot-pounds the work per hour of the weight of steam admitted to the cylinder. Let W represent this weight and h^1 the cost of producing it, including the cost of fuel and the hourly interest on the cost of the boilers; then $\frac{h^1}{W} = h$ will be the cost of producing one pound hourly.

Let K^1 represent the total interest on the cost of the engine, A the area of the piston, and K the interest per hour of the cost of the engine per square foot of the piston, then

$$K^1 = K.\ A.$$

The assumption made is, that the work in foot-pounds divided by the cost of the work must be a maximum for greatest economy; that is, if y be this ratio

$$y = \frac{p_e V_2}{h.\ W. + K.A.} \text{ must be a maximum.}$$

Let l represent the length of stroke, n the number of revolutions per hour, r the ratio of expansion, then

$$W = \frac{A.l.n}{r}\ .\ D$$

D being the weight of a cubic foot of steam at the initial pressure.

The above expression then becomes

$$y = \frac{p_e\ V_2}{h\ .\ \frac{A.l.n}{r}\ .\ D + K.A\ .}$$

$$= \frac{A.l.n \left[\frac{p_1}{\gamma - 1} \left(\frac{\gamma}{r} - \frac{1}{r\gamma}\right) - p_2\right]}{h\ .\ \frac{A.l.n}{r\ v_1} + K.A.}$$

r only being supposed variable in the second member, and in which p_1 is the initial pressure γ, the exponent of v in the equation of the adiabatic curve of expansion, $pv^\gamma = p_1 v_1^\gamma =$ constant, and p_2 the back pressure.

The result of the operation for finding the maximum of y by the calculus is an equation between the values of V_2, K, h, A and r, as follows, supposing y to be be $\frac{10}{9}$

$$h \frac{A.l.n}{v_1} \left(p_1 r^{-\frac{10}{9}} - p_2\right) = K.A \left[p_1\ 10 - 10 r^{-\frac{1}{9}}\right]$$

This result and the former expressions will be recognized as those given in a paper read at the Hartford meeting of the Society by Messrs. Wolff and Denton, as being substantially the same as those

of Rankine. In this expression v_1 represents the value of one pound of steam at the initial pressure p_1, and $\frac{1}{v_1} = D$, D being the weight of a cubic foot of steam at the same pressure.

The usual mode of stating the efficiency of the steam in the cylinder of an engine is

$$E = \frac{p_e V_2}{H \cdot \frac{A\,l\,n}{r} D \cdot \times 772}$$

In this expression no element of cost enters, but the denominator represents the number of foot-pounds of work which enters, *as heat,* into the cylinder each hour.

H being the heat of evaporation, $\frac{A.l.n}{r} D$ the weight W, and 772 the dynamic equivalent of a unit of heat. The maximum of this expression corresponds to such a degree of expansion by the adiabatic curve that the terminal pressure in the cylinder is just equal to the back pressure p_2. *The maximum of* y will correspond to a less degree of expansion, or to more steam used in proportion to the work developed.

The work $p_2 V_2$ for any degree of expansion may be represented by a rectangle of which the base is V_2 and the altitude p_e. The denominator may also be represented by a rectangle having the same base, but with a much greater altitude. The efficiency E is the ratio of these rectangles, or what is the same thing, the ratio of the altitudes of the rectangles. A somewhat similar process may be applied to the ratio giving the value of y, as explained by Rankine and worked out for varying values of the mean effective pressures and for various engines and boilers by Messrs. Wolff and Denton in the paper above referred to.

The graphical process thus introduced by Rankine shows at once the ratio of expansion which gives the maximum of y, or the rate of expansion which gives the greatest number of foot-pounds for the least amount of money, according to the author, *when his assumed premises are accepted.*

In regard to the maximum of E, the mechanical efficiency, a discussion by Rankine, found in his work on the steam engine, is a legitimate and correct one, but the theorem which introduces the cost is, at

least when applied to modern steam engines, fallacious, inasmuch as the *premises assumed are not true.* It is a very ingenious discussion, considered as a mere mathematical problem, admitting all the assumptions; but if these assumptions are not correct it must be considered, as it is practically, mere play of mathematics without practical value. In this presentation of the matter, from a purely theoretical standpoint, the secondary influences of cylinder condensation, clearance, etc., are not considered.

The first false assumption is in the total cost of making steam per hour, $h.W.$ h is a constant, and is the cost of evaporating one pound of steam, including interest on cost of boiler; and when multiplied by the weight W it is assumed that the cost of a boiler constructed to evaporate this quantity of steam varies with the quantity of steam produced.

Whereas it is well known that the *same boiler* will produce more or less steam depending simply on the draft, and upon other circumstances not introduced. No exact relation of a general nature exists between the cost of a boiler and the quantity of steam it produces. Moreover, the chimney, or other appliance for producing draft, is an essential part of the boiler, and its costs should be included in the cost of making steam. The relation of cost to the quantity of steam produced is thus still more uncertain.

In the discussion of Rankine's theorem, by Messrs. Wolff and Denton, and by Prof. Thurston, who adopts and endorses their discussion, the quantity h is made to include also hourly wages of firemen, coal-passers, interest, a redemption annuity, or sinking fund, for the whole *supposed* lifetime of the boiler, etc.

This accumulated quantity h, multiplied by the weight of steam used at different grades of expansion, is taken at the hourly cost of making the quantity of steam W. It is hardly necessary to dwell on the fallacy of these assumptions, as the error must be apparent from the above statement, which will hardly be denied by those conversant with steam apparatus.

The second false assumption is in making the total cost of an engine proportional to the area of the piston.

The value of K in the formula is the interest on the cost of the engine divided by the area of the piston. It is well known that the cost of modern steam engines does not vary as the piston area, nor as the volume of the cylinder.

The following statement, taken from the yet unpublished records of the Tenth Census, has been furnished me by Mr. Charles H. Fitch, special agent of the census, who has been engaged under my direction in determining the statistics of engines and boilers.

Cylinder Capacity and Cost.

"The following table exhibits comparatively the relations of cylinder capacity, weight and cost in steam engines of the horizontal plain slide valve type, rated at from eight to one hundred horse-power:

Cylinder Capacity of Engine.	Ratio of stroke to diameter.	Price per cubic foot of cylinder.	Weight of engine per cubic foot of cylinder (lbs).
0·19	2·00	$1,910 00	8,684
0·27	1·71	1,392 00	6,296
0·46	2·00	1,113 00	7,500
0·59	1·77	952 00	7,118
0·72	1·60	872 00	6,944
0·90	2·00	749 00	6,264
1·31	1·66	707 00	6,183
1·58	2·00	644 00	5,860
1·79	1·43	633 00	5,168
2·14	1·71	569 00	5,023
2·79	1·50	497 00	4,337
3·48	1·87	451 00	4,253
3·53	1·33	509 00	5,241
4·41	1·66	448 00	4,736
4·35	1·20	517 00	4,638
5·44	1·50	459 00	4,964

"It is obvious that no formula can truly exhibit the relative changes of price and capacity, which does not consider the actual sizes of engines

compared. The examples cited present an unusual degree of uniformity, a line of engines rated at uniform piston speed, and of similar excellent workmanship and finish.

"Between different styles and qualities of engines there can be no very definite comparison. For the same cylinder capacity a finely built, closely fitted engine may cost twice as much as an engine of inferior workmanship."

Rankine evidently assumed that the cost is proportional to the volume of the cylinder or to piston area, because this is the only assumption that will enable an engineer to *design an engine with a given power*, the steam being cut off at the point of the stroke determined by his theorem.

He gives an example by designing an engine of 100 HP, having first found the proper ratio of expansion for a cylinder having a unit area of piston and a given speed. He finds the cost of a 100 HP engine of the same speed to be by his process £6018, an assumed cost of £250 per square foot of piston. Of course, if his 100 HP engine, with all its appliances, was found, when actually constructed, to cost more or less than £6018 the whole process becomes invalidated.

It would seem that nothing more need be said to exhibit the fallacy of the assumptions or premises on which the mathematical work of the whole discussion is based. But we may place these fallacies on broader grounds.

There cannot be, from the nature of finance and pure mechanics, any exact mathematical relation between abstract mechanical laws and financial operations.

The former are invariable and immutable, the latter are dependent upon bargain and sale, the efficacy of human labor or upon human necessities, and sometimes on human follies.

No more conspicuous illustration of these truths, it seems to me, could be given than this plausible, but false application of mathematics, and especially of the calculus, to a problem in which the cost of an apparatus and its mechanical performance are introduced as elements of a formula which is claimed to be general in its nature and practically correct in its applications.

Looking at Rankine's theorem from another point of view it is claimed that although it is not applicable *for designing engines*, yet after an engine and boiler have been completed, and the actual cost of the whole plant is known, it is then practicable to determine for that

engine the point of cut-off which will give the most power for the money already and actually expended.

Assuming, for instance, the principle that the power divided by its cost should be a maximum, the same mathematical expression

$$y = \frac{p_e V_2}{h.W + K.A}$$

is merely restricted to an apparatus of which the cost is known.

Taking this view of the problem the absurdity of including in any manner in the variable term of the denominator ($h.W$) the interest on the cost of the boiler, firemen's wages, insurance, depreciation of value from use, repairs, etc., is evident at once; because none of these items vary with the quantity of steam used.

Moreover, it is not necessary to estimate the interest on the cost of the engine K by the square foot of piston, but the formula, admitting for the sake of argument, its validity, should be

$$y = \frac{p_e V_2}{h.W + K}$$

in which $h.W$ includes only those items of cost which vary with the quantity of steam used, and in which K includes all the constant hourly expenditures of the plant, including boiler and engine. We should thus have to include in h only the cost of making one pound of steam per hour estimated from the price of coal, while K would necessarily embrace the following items.

1. Hourly interest on cost of boiler.
2. " " " engine.
3. " " " chimney.
4. " " " boiler room and engine room.
5. Wages of Engineer and fireman per hour.
6. Insurance per hour.
7. Taxes per hour.
8. A portion of the wages of general foreman and manager per hour.
9. Estimated repairs per hour.
10. Sinking fund for redemption of cost of boiler and engine, estimated to last (blank) years.

Everything, in fact, must be included which can reasonably be charged to the cost of the power, as distinguished from expenditures for utilization of power and other expenses connected with it.

In this mathematical formula for which it has recently been claimed that it furnishes "*the only correct solution which has ever been presented*" and that it is of "*immediate practical use*," we find all of these quantities.

Let us see how they are to be determined numerically:

Interest—Who shall establish the rate?

Cost of engine and boiler—What shall it include?

Boiler and engine room and setting—How shall the cost be separated from that of the rest of the plant, in a manufacturing establishment, or in a steamship from other parts of the structure?

Wages of engineers and firemen—What shall be done if these wages should happen to change from time to time?

Insurance—When a whole establishment is insured what part shall be charged to power?

Salaries of general foreman and manager—What part shall be charged to power?

Repairs—What amount shall be *estimated?*

Sinking Fund—How *estimated?*

Who can estimate the life of a boiler or an engine?

All or nearly all of the above quantities can be assumed only by mere guesswork—there is not a shadow of a guide or a rule for most of them, not even the results of experience which so often aid in the solution of practical problems.

If the quantities in the formula are arrived at by mere guess, and without experience to guide the person who guesses, of what value are the results?

A good deal has been said in this connection about the "business man's cut-off" as distinguished from the scientific man's cut-off. This wretched process is like that of finding the correct time, so admirably described by John Phœnix in his burlesque exploring expedition from San Francisco to the "Mission," one of its suburbs. The party, after attempting for a whole night to determine the true time by observations of the stars with a transit, which could not be properly adjusted, concluded that it would be just as well to step into a corner grocery and get the time from the grocer's clock.

There is one other important consideration which should not be lost sight of in applying this method to a given plant, viz., that not until all these questions of cost have been successively guessed at and thus established, and not until after the boiler and engine have been erected,

ready for running, will the manufacturer or the steamship owner know what power he has at his disposal. The power developed at the "business man's" economical point of cut-off depends on these items of cost, and he must accept what his guesswork has given him.

Possibly the power thus available will not run his works or his ship, and he may find that in attempting this mode of economy he is a greater loser in the end for want of sufficient power or from having too much power. The moment dollars and cents enter into a problem it ceases to be a mechanical, and becomes a financial one; and in such problems there must always be two sides to the account.

A horse-power as power has no standard or intrinsic value; its value depends entirely upon its serving fully and precisely the objects for which it is employed.

A definite amount of power just sufficient for performing a given work has a certain value, where one-half or indeed any less power might be of no value, and more power might involve loss.

Steam-power is like a manufactured article, and the question of preventing waste in the manufacture, by high grades of expansion and costly engines, is one in which all the conditions and circumstances of the use of the power must be considered. It cannot be narrowed down to a mere ratio between the cost of the engine and the cost of fuel as is claimed in the new method.

The attempt to apply this new method to marine engines in public vessels, where no questions of interest and of profit and loss can enter, is not the least of the absurdities that have marked the discussion of the subject.

The introduction of the sinking fund idea as a part of the cost involves another absurdity, because the operation of a sinking fund is to reduce the principal of the debt, and the value of the quantity K, in the formula assumed as constant, is not a constant under this assumption, but a variable quantity, practically a vanishing quantity. Thus the validity of the mathematical discussion is destroyed, even if there were no other elements of unsoundness in the process. It seems to me unfortunate that crude ideas on this subject should have been put forth as the results of exact scientific investigation, and a theorem practically abandoned by its author, invoked to persuade business men that our most eminent and successful engineers of the present day have been practically ignorant of correct principles regarding the economical use of steam.

Nothing tends more to bring science into disrepute with those engaged in industrial pursuits than the hasty announcement in the name of science of conclusions or results, as truths, which are merely personal and unverified speculations, or false deductions from assumed and unproved premises.

THE SPECIFIC HEAT OF PLATINUM, AND THE USE OF THIS METAL IN THE PYROMETER.

By J. C. Hoadley.

In a paper which I had the honor to present to the American Society of Mechanical Engineers at the meeting held at Hartford in May, 1881, I gave, as the best estimate of the mean specific heat of platinum which I was able to form—based on the data to be found in Clarke's "Constants of Nature"—0·0333, equal to one-thirtieth of the specific heat of water under standard conditions; and apparently uniform, or nearly so, at all temperatures ordinarily attainable. At the same time I stated that a careful study of the original memoirs might disclose such reasons for assigning greater weight to the results obtained by some experimeters than to the varying results obtained by others, as to lead to a probable mean result much more trustworthy than that of my first crude approximation.

Such a study of the original memoirs, and a careful discussion of the several experiments therein described, for which I had neither the requisite facilities nor the necessary leisure, was made during his summer vacation by Mr. Silas W. Holman, Instructor in Physics at the Massachusetts Institute of Technology, who generously placed at my disposal the interesting and valuable fruits of his labors.

Mr. Holman first clearly points out the distinction between the terms "true specific heat" and "mean specific heat." The *true* specific heat of any substance at $t°$, is the amount of heat, expressed in heat units, required to raise the unit weight of the substance from any temtemperature $t°$ to $t° + 1°$, or more properly from $t°$ to $t° + dt$, whence we may write the true specific heat at $t° = \frac{dh}{dt}$ = first differential coefficient of the heat with regard to the temperature (of course

not passing through change of state, as from solid to liquid, or from liquid to gaseous).

On the other hand, the *mean* specific heat from 0° to $t°$ is the amount of heat, expressed in heat units, required to raise the unit of weight from 0° to $t°$, divided by the number of degrees of this temperature $t°$, 0° in this case being 0°C. For Fahrenheit degrees the equivalent expression is the amount of heat required to raise the unit weight from 32° to $t°$, divided by the number of degrees embraced between 32° and $t°$.

Confining ourselves, for the sake of simplicity, to centigrade degrees, for the present, let h_t, h_{t_1}, etc., = number of heat units required to raise unit weight from 0° to $t°$, $t_1°$, etc., respectively. Then let $\frac{h_t}{t}$, $\frac{h_{t_1}}{t_1}$, etc., = mean specific heat from 0° to $t°$, $t_1°$, etc., respectively. Also, $h_{t_1} - h_t$ = number of heat units required from $t°$ to $t_1°$. Then $\frac{h_{t_1} - h_t}{t_1 - t}$ = m. sp. ht. from $t°$ to $t_1°$. Now $h_t = t(a + bt + ct \ldots)$,

$$\text{and } h_{t_1} = t(a + b_{t_1} + ct_1^2 + \ldots).$$

$$\therefore h_{t_1} - h_t = a(t_1 - t) + b(t_1^2 - t^2) + c(t_1^3 - t^3) + \ldots$$

$$\therefore \frac{h_{t_1} - h_t}{t_1 - t} - a + b\,(t_1 - t) + c\,(t_1^2 - 2tt_1 + t^2) + d\,(\ldots \text{ etc.})$$

which, at the limit when t_1 approaches t, becomes the *true* specific heat at $t° = \frac{dh}{dt} = a + 2bt + 3ct^2 + 4dt^3 + \ldots$, while the *mean* specific heat from 0° to $t° = \frac{h_t}{t} = a + bt + ct^2 + dt^3 + \ldots$ etc.

The neglect of this obvious distinction, and the confusion of *mean* with *true* specific heat, vitiated my work. The location of points on my diagram, representing mean specific heat determinations at points midway between the two extremes for which the determinations were made, was erroneous and confusing. For instance, the determination 0·03818, for the mean specific heat 0° to 1200°C., should have been located at 1200° on my diagram, instead of at 600°, as I located it.

Mr. Holman also introduces Violle's results for the specific heat of platinum, which he considers the best results by far which we possess.

In discussing the results Mr. Holman remarks, as I had already

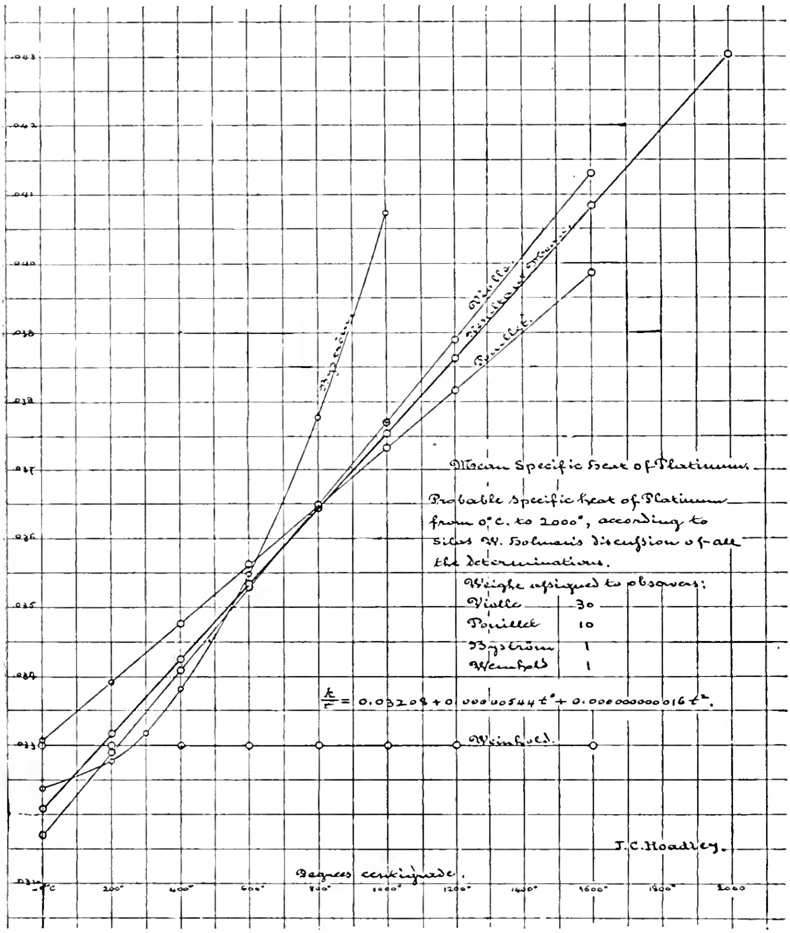
done, that every observer has found for platinum an increase of specific heat with increase of temperature, and that the *rates* of increase found by the various observers are not very diverse. In the expression $\frac{h_t}{t} = a + bt + ct^2 + dt^3 + \text{etc.}$, we wish to find the most probable values of the constants a, b, c, d, etc., up to a limiting temperature, $t =$, let us say, 1000°C. Now, of these constants a is the *true* specific heat at 0°C. To obtain this, we may, if we choose, collect all observations at this temperature, and, giving proper weight to each, take the mean, this constant being entirely independent of the others. Mr. Holman has chosen another method, by which, however, he has arrived at almost identically the same results which the above method would have given.

Taking each trustworthy set of observations, he has found, by the graphical method, or by the method of least squares, the value of a, b, and c, for that set, if the experimenter has not done so himself. Then, calculating for a series of temperatures sufficiently near together—at intervals of 200°C. up to 1600°C., the mean specific heat for that temperature—and assigning to each set its proper weight, as nearly as may be, he takes a mean of each column.

From these means may be immediately calculated the values of a, b, and c. Higher powers than the square of t are useless in the present state of our knowledge, and even that may be discarded in the case of platinum; but it must be retained in the case of all other substances.

But if we prefer a value of a deduced from more observations, or from any particular set of low temperature observations, we can introduce such value without affecting the accuracy of the values of b and c. Mr. Holman gives in a table, which I reproduce, a summary of his interesting and valuable work on platinum, and, farther on, a summary of the results of various observers. To Violle he gives a weight of 30, as his determinations have the widest range (except Pouillet's, which have the same range), and are, in Mr. Holman's opinion, by far the most thorough, careful and accurate, and Violle being a skillful observer. To Pouillet's determinations Mr. Holman assigns a weight of 10, as having the same range as Violle's, but without the advantage of all the facilities for accurate work possessed by the latter. Byström's results are apparently pretty good, but extend only to 300°C., and are therefore entitled to but little weight when extrapolated to 1000°C.

Weinhold's results have not equal concordance among themselves, nor do they appear to have been made with the same degree of care and skill as even Pouillet's.



The above $\frac{k}{t} = 0{\cdot}03208 +$ etc., should read $k_t = 0{\cdot}03208 +$ etc.

To Byström's and Weinhold's determinations, which he considers of little value, Mr. Holman assigns a weight of one each.

In all cases it will be noted that the temperatures are upon the air thermometer.

Mean Specific Heat of Platinum from 0° to t° C.

Observer.	Wt.	$t°=0°$	200°	400°	600°	800°	1000°	1200°	1600°
Violle................	30	·0317	·0329	·0341	·0353	·0365	·0377	·0389	·0413
Pouillet............	10	·03307	·03392	·03477	·03562	·03649	03732	·03817	·03987
Byström...	1	·03239	·03278	·03381	·03547	·03778	·04073	·04431	·05341
Weinhold..........	1	·0330	·0330	·0330	·0330	·0330	·0330	·0330	·0330
Means............. ..		·03208	·03315	·03423	·03533	·03758	·03645	·03871	·04105

From the above means Mr. Holman deduces approximations which he considers sufficiently exact as the mean specific heat from 0° to $t°$, $k_t = 0·03208 + 0·00000544\, t° + 0·000000000016\, t^2$, or, if ct^2 be dropped, $k_t = 0·03208 + 0·00000547\, t$, for platinum.

It will be observed that when the third term, ct^2, is omitted, Mr. Holman's curve, when represented graphically, becomes a straight line, and that the eighth decimal in the constant b becomes 7 instead of 4.

Mr. Holman deduces, in a similar manner, but with less exactness, on account of the paucity of material, the probable mean specific heat of iron from 0°C. to 300°, 600° and 1000°C., as exhibited in the subjoined table:

Mean Specific Heat of Iron from 0° to t° C.

Observer.	Wt.	$t = 0°$C.	300°	600°	1000°
Weinhold...........	5	·10591	·13150	·16907	.2378
Bède.....................	3	·1053	·1266	·1479	·1763
Byström..............	2	·11164	·11703	·13100	·1629
Means......		·10687	·12714	·15510	·2044

From these means is deduced the following equation for the mean specific heat of iron:

$$k_t = 0·10687 + 0·0000547\, t + 0·0000000428 t^2$$

In this expression, the third term, ct^2, cannot be neglected; the line

is distinctly a curve. These constants are in all cases for centigrade degrees, and must be multiplied by $\frac{5}{9}$ to reduce them for Fahrenheit degrees. Performing this multiplication, the expressions become, in Fahrenheit degrees:

For the mean specific heat of platinum, from 32° to t°F.:

$$k_t = 0{\cdot}03208 + 0{\cdot}00000302\dot{2}(t - 32) + 0{\cdot}000000000009\,(t - 32)^2$$

or, omitting the last term, as we may safely do, for platinum:

$$k_t = 0{\cdot}03208 + 0{\cdot}00000304(t^\circ - 32)$$

For the mean specific heat of iron, from 32° to t°F:

$$k_t = 0{\cdot}10687 + 0{\cdot}0000304(t - 32) + 0{\cdot}0000000238\,(t - 32)^2$$

For pyrometric purposes, iron and all other metals save platinum may be left out of consideration. For platinum, my assumption of $\cdot 03\dot{3}\dot{3} = \frac{1}{30}$, as the uniform specific heat at all ordinary temperatures, is found to be correct only at a certain temperature, namely, 446·15° Fahr., equal to 230·108°C. At all temperatures below this my assumption, $0{\cdot}3\dot{3}\dot{3}$, is too high; at all higher temperatures it is too low.

The rate at which the mean specific heat changes is, per degree F., 0·00000304 deg.

For the 32°F. between 0°F. and 0°C., the difference in m. sp. h. is $32 \times 0{\cdot}00000304 = 0{\cdot}00009728$, and this difference subtracted from the mean sp. h. of Pt. at 0°C. will give the m. sp. h. of Pt. at 0°F. thus: $0{\cdot}03208 - 0{\cdot}00003728 = 0{\cdot}03198272$.

Of course we may substitute this value of the first term, a, this number, ·031983 (specific heat of platinum at 0°F.), for the number in the table, 0·03208 (sp. ht. of Pt. at 32°F.), when t° will be the temperature F. from 0°F., and the 32° must not be subtracted from t.

The assumption, $0{\cdot}03\dot{3}\dot{3}$, for the first approximation in proportioning the pyrometer, is a very convenient one. Quite correct for the temperature indicated by 446·195°F. = 230·108°C., which is about the upper limit of accurate indication by the mercurial thermometer, the corrections to be applied from this point upward are all in the same direction, all *minus* For example, 1050·4° observed, = 1000° corrected; 2022·4° observed, = 1800° corrected.

The subjoined table has been computed for the Fahrenheit scale and zero, by the use of the formula

$$k_v = 0{\cdot}031983 + 0{\cdot}00000302\dot{2}\,t + 0{\cdot}000000000009\,t^2$$

Temperatures, in deg. Fahr., corresponding with specific heat in column 2.	Mean sp. ht. of platinum, computed for each 100 deg. Fahrenheit.	Differences of sp. ht. per each 100° Fahr.	Ratio of computed to assumed sp. ht., viz., $\frac{1}{30}$ water = 0·03333.	Differences of ratios for each 100° Fahr.	Observed temperatures by pyrometer at assumed ratio: w. to pt. ball 100 to 1.	Differences of observed temperatures per 100° Fahr.
1	2	3	4	5	6	7
0	·031983		·95950		—1·3	
32	·032080		·96240		30·8	
100	·032286	303	·96857	907	96·9	98·2
200	·032588	302	·97764	907	195·5	98·6
212	·032624		·97783		207·5	
300	·032891	303	·98672	908	296	100·5
400	·033193	302	·99580	908	398·3	102·3
446·195	·033333		1·00000		446·2	
500	·033496	303	1·00489	909	502·4	104·1
600	·033800	304	1·01399	910	608·4	106
700	·034103	303	1·02309	910	716·2	107·8
800	·034406	303	1·03219	910	825·8	109·6
900	·034710	304	1·04130	911	937·2	111·4
1000	·035014	304	1·05042	912	1050·4	113·2
1100	·035318	304	1·05954	912	1165·5	115·1
1200	·035622	304	1·06867	913	1282·4	116·9
1300	·035927	305	1·07780	913	1401·1	118·7
1400	·036231	304	1·08694	914	1521·7	120·6
1500	·036536	305	1·09608	914	1644·1	122·4
1600	·036841	305	1·10523	915	1768·4	124·3
1700	·037146	305	1·11438	915	18 4·5	126·1
1800	·037451	305	1·12354	916	2022·4	127·8
		306		917		129·7

Temperatures, in deg. Fahr., corresponding with specific heat in column 2.	Mean sp. ht. of platinum, computed for each 100 deg. Fahrenheit.	Differences of sp. ht. per each 100° Fahr.	Ratio of computed to assumed sp. ht., viz., $\frac{1}{30}$ water = 0·03333.	Differences of ratios for each 100° Fahr.	Observed temperatures by pyrometer at assumed ratio: w. to pt. ball 100 to 1.	Differences of observed temperatures per 100° Fahr.
1	2	3	4	5	6	7
1900	·037757		1·13271		2152·1	
		306		917		131·7
2000	·038063		1·14188		2283·8	
		305		917		133·4
2100	·038368		1·15105		2417·2	
		306		918		135·3
2200	·038674		1·16023		2552·5	
		307		919		137·2
2300	·038981		1·16942		2689·7	
		306		919		139·0
2400	·039287		1·17861		2828·7	
		307		920		140·8
2500	·039594		1·18781		2969·5	
		306		920		142·7
2600	·039900		1·19701		3112·2	
		307		921		144·6
2700	·040207		1·20622		3256·8	
		307		921		146·4
2800	·040514		1·21543		3403·2	
		308		922		148·3
2900	·040822		1·22465		3551·5	
		307		923		150·1
3000	·041129		1·23388		3701·6	
		308		923		152·0
3100	·041437		1·24311		3853·6	
		308		923		153·9
3200	·041745		1·25234		4007·5	
		308		924		155·7
3300	·042053		1·26158		4163·2	
		308		925		157·6
3400	·042361		1.27083		4320·8	
		308		925		159·5
3500	·042669		1·28008		4480·3	
		309		926		161·3
3600	·042978		1·28934		4641·6	
		309		926		163·2
3700	·043287		1·29860		4804·8	
		309		927		165·1
3800	·043596		1·30787		4969·9	
		309		927		166·9
3900	·043905		1·31714		5136·8	
		309		928		168·8
4000	·044214		1·22642		5305·6	

The corrections *below* 446·195° are *plus.*

The lines 32° and 212° are inserted for convenience in testing the pyrometer for verification. At 32° true temperature the indicated temperature is 30·8, a correction of +1·2°. At 212°, or the boiling point, the indicated temperature is 207·5, a correction of +4·5°. In my pyrometer the water and so much of the metal as shares its temperatures being together equal to 2 pounds of water, and the platinum ball being 0·6 lb., and the assumed sp. ht. $\frac{1}{30}$ that of cold water, the assumed ratio is 100 to 1; and with good thermometers having about 0·8 in. to 1°— graduated to 0·1°, on which $\frac{1}{40}$ or even $\frac{1}{50}$ of a degree can be accurately read, the greatest error need not exceed 6°. By skillful manipulation error is nearly eliminated.

It will be observed that the table is carried up to 4000°F., the reputed melting point of platinum.

Since the highest temperature at which the sp. ht. of platinum has been determined is 1200°C. = 2182°F., all the numbers in the table above 2200° must be received with a certain degree of gradually increasing reserve; and the analogy of other metals leads us to suppose that between 3000° and 4000° the specific heat may rise more rapidly than the formula indicates. There can be no great error up to 3000°—and between that limit and 4000° it can only be said that the figures here given are the best attainable, and if of little practical use may sometimes be better than none.

Action of Colored Lights on Vegetables.—M. G. Mernet gives the following results of observations: 1. The luminous intensity necessary for white light to decompose carbonic acid is a little less than that which is required for the most active colored rays. 2. Under a clear sky and burning sun the action begins and ends instantaneously in light and shade. 3. For a temperature of 15° to 25° (59° to 77° F.), but under a cloudy sky or a luminous mist the colored rays are inactive. 4. All the colored rays are efficacious, but in different degrees. 5. The yellow rays always have the greatest activity, the red rays the least. 6. Under the influence of some unknown cosmic curve the proportional influence of the orange and red rays, and still more of the violet, indigo and blue rays, is variable. 7. Partial results of experiments indicate the following order of activity: yellow, orange, red, violet, indigo, blue, green. 8. For equivalent durations of illumination the work of the colored rays is sensibly equivalent to the work of the white.—*Le Genie Civil,* ii, 305. C.

BELL CHIMES IN PHILADELPHIA AND OTHER PLACES.

By John W. Nystrom.

There are four peals of bells in Philadelphia, namely, at the Churches of *Christ, St. Peter, St. Stephen* and *St. Mark;* of which only one peal is cast in this country and the other three in England.

Peal of Christ Church.

The oldest peal in Philadelphia is that of Christ Church, Second street above Market, consisting of eight bells cast in the year 1754, by Lester & Pack, of the foundry which now bears the name of Mears & Stainbank, 267 Whitechapel, London.

The whole peal weighs 9,000 pounds, and cost £560 in London (about 30 cents per pound).

Dimensions of the Bells at Christ Church.

Bells and Keynote.	Actual Vibrations	Diameter. Inches.	Soundbow. Inches.	Soundbow. Strokes.	Weight. Pounds.	Timbre.
Tenor F	352	$46\frac{3}{8}$	$3\frac{1}{4}$	0·701	2040	566
2d G	394	40	$2\frac{7}{8}$	0·718	1400	535
3d A	431	39	$2\frac{78}{100}$	0·717	1295	570
4th B♭	470	37	$2\frac{11}{16}$	0·727	1116	536
5th C	505	34	$2\frac{5}{8}$	0·772	921	564
6th D	593	32	$2\frac{1}{2}$	0·780	777	590
7th E	660	$29\frac{1}{2}$	$2\frac{1}{2}$	0·848	660	562
Treble F	702	$29\frac{3}{4}$	$2\frac{3}{4}$	0·924	735	550

Total, 8944 pounds.

The tenor broke in the year 1835, and was recast in the same foundry but of a smaller size, so that the old clapper was too long and,

when tolled for the first time, a big piece was broken off the lip of the new tenor, which is now rung in that condition and weighs 2,040 pounds.

The fifth bell, C, was broken in the year 1865, and recast in the same foundry, but became lower in tone or nearer B than C.

The pitch of tone of the bells agrees nearly with that established by the Stuttgart Congress in the year 1834, or 80 years after the bells were cast.

The bells are hung to swing for change ringing, which was at the height of excitement at the time the peal was cast, but that style of bell-ringing has since gradually declined until now the chimes are generally rung by swinging the clapper with a rope attached thereto, although the bells may be hung for swinging.

Change Ringing.

Change ringing is more of a curiosity in mechanic arts than art of music.

A band of English bell-ringers visited this country in the year 1850 and rang the peal of Christ Church on June 9th, under the direction of Mr. Henry W. Haley, who managed to ring 5,040 changes in three hours and fifteen minutes, with consummate skill, and being the first or probably the only change ringing in the United States of America up to this time, was duly appreciated by many attentive listeners.

Celebrated bell-ringers amuse themselves with the rule of permutation, to find how many changes can be rung on a given number of bells, and what time it takes to ring each number. The bells to ring about 96 strokes per minute in continued succession, without melody.

The product of the number of bells and number of changes gives the total number of strokes. (See table, next page.)

The writer has lately constructed a peal of four bells, and arranged for it eight different pieces of music, selected from operas and various songs, which have been played on the peal. By such arrangement, millions of changes can be rung on four bells, whilst by the ordinary change ringing only 24 unmelodic changes can be made.

The writer has rung the well-known song "Far over the Stars is Rest" and other songs upon the peals at St. Mark's and St. Stephen's Churches.

Table for Change Ringing.

Number of bells.	Number of changes that can be rung.	Time required to ring the changes.
2	2	Two seconds.
3	6	Twelve seconds.
4	24	One minute.
5	120	Five minutes.
6	720	Half an hour.
7	5,040	Three hours and a half.
8	40,320	One day and four hours.
9	362,880	Ten days and twelve hours.
10	3,628,800	Fifteen weeks.
11	39,916,800	3 years and 60 days.
12	479,001,600	37 years and 355 days.
13	6,228,020,800	500 years.
14	87,178,291,200	7,000 years.

Peal of St. Peter's Church.

The peal of eight bells at *St. Peter*, corner of Third and Pine streets, was presented to that Church in the year 1842, by Benjamin Wilcocks, a member of the congregation. The bells were cast by Mears, 267 Whitechapel, London, and brought to Philadelphia, free of charge, by Capt. Henry Miercken, also a member of the parish.

The pitch of tone agrees nearly with the English scientific pitch, making C = 512 vibrations per second, which is one quarter of a note lower than the Stuttgart pitch.

Dimensions of the Bells at St. Peter's.

Approximate Key-note.	Actual Vibrations	Diameter. Cast.	Diameter. Toned.	Soundbow. Inches.	Soundbow. Stroke.	Weight. Pounds.	Timbre.
Tenor F	343	$44\frac{1}{2}$	$44\frac{1}{2}$	$3\frac{1}{16}$	0·689	1733	528
2d G	384	$39\frac{3}{4}$	$39\frac{3}{4}$	$2\frac{3}{4}$	0·694	1212	533
3d A	424	37	37	$2\frac{1}{2}$	0·668	1073	574
4th B ♭	454	$35\frac{1}{2}$	$35\frac{1}{2}$	$2\frac{1}{2}$	0·705	983	558
5th B	484	$33\frac{1}{4}$	32	$2\frac{3}{8}$	0·729	774	528
6th C	512	31	31	$2\frac{7}{16}$	0·787	731	519
7th C♯	542	$30\frac{1}{2}$	$29\frac{1}{4}$	$2\frac{7}{16}$	0·834	638	498
Treble D	566	$28\frac{1}{2}$	$28\frac{1}{2}$	$2\frac{3}{8}$	0·833	608	536

Total, 7,752 pounds.

The bells are hung to swing for change ringing, but have not been so used, as far as the writer knows, but the clappers are swung by ropes for chime ringing.

The tenor is chipped here and there, inside the soundbow, for lowering the note.

The second bell is not chipped nor turned.

The third bell is turned off half an inch on the lip, for raising the note.

The fourth bell is very much chipped all round, inside the soundbow, for lowering the note.

The fifth bell is turned off five-eighths of an inch on the lip, for raising the note.

The sixth bell is not chipped nor turned.

The seventh bell is turned off one-half of an inch on the lip.

The treble is very much chipped all round, inside the soundbow, for lowering the note.

Peal at St. Mark's Church.

The peal of eight bells at St. Mark's Church, Locust street, between Sixteenth and Seventeenth streets, was cast by Mears & Stainbank, London. The four largest were cast in the year 1876 and the four smallest in 1878.

The cost of the first four bells, including a new floor in the tower and frames for the entire peal, was $4,980 05, in 1876.

The four smaller bells, . 1,977 83, in 1878.

Total, . . $6,966 88.

This includes freight from London and hanging of the eight bells.

Dimensions of the Bells at St. Mark's Church.

Approximate Key-note.	Actual Vibrations.	Diameter. Cast.	Diameter. Toned.	Soundbow. Inches.	Soundbow. Stroke.	Weight. Pounds	Timbre.
Tenor F	352	47	$46\frac{1}{8}$	$3\frac{1}{16}$	0·643	2006	618
2d G	396	$42\frac{3}{8}$	$41\frac{5}{8}$	$2\frac{11}{16}$	0·634	1407	634
3d A	442	39	$38\frac{3}{4}$	$2\frac{5}{8}$	0·681	1167	614
4th B♭	469	37	$36\frac{1}{8}$	$2\frac{1}{2}$	0·676	983	618
5th C	528	34	$33\frac{1}{4}$	$2\frac{1}{2}$	0·735	867	586
6th D	593	$32\frac{1}{4}$	32	$2\frac{1}{2}$	0·775	788	598
7th E	664	30	$29\frac{3}{4}$	$2\frac{7}{16}$	0·814	646	593
Treble F	704	29	$27\frac{7}{8}$	$2\frac{6}{16}$	0·842	623	579

Total, 8,487 pounds.

The pitch of tone of the bells at St. Mark's Church agrees very nearly with the Stuttgart standard pitch, which is one quarter of a note above the English scientific pitch.

The bells are hung to swing for change ringing, but have never been so used, for the reason that there are no such bell-ringers in Philadelphia, nor is the tower in which the bells are hung strong enough.

for change ringing, and they are therefore chimed by hammers striking the outside of the soundbows.

Peal at St. Stephen's Church.

The peal of nine bells at St. Stephen's was presented to that Church by Mrs. Eliza Howard Burd, September 19, 1853. Messrs. Jones & Hitchcock, of Troy, N. Y., who were the only bidders, secured the contract for these bells at the rate of 32 cents per pound. The peal was completed and rung in December, 1853. Only the tenor is hung to swing, the other bells are hung stationary and their clappers swung by ropes for ringing. The tenor is also rung by swinging the clapper.

Dimensions of the Bells at St. Stephen's Church.

Intended Keynotes.	Actual Keynotes. Fund'tal	Partials.		Actual Vibrations.	Diamet'r Inches.	Soundbow. Inches	Strokes.	Weight Pounds.	Timbre.
Tenor D	D	F·6	B·1	288	$52\frac{7}{8}$	$3\frac{1}{4}$	0·615	2838	590
2d E	E	G·6	C·9	332	47	3	0·638	2112	584
3d F♯	F·8	A·2	C	358	$42\frac{1}{4}$	$2\frac{11}{16}$	0·633	1570	570
4th G	G·1	A♯·6	C·1	386	$40\frac{3}{4}$	$2\frac{5}{8}$	0·645	1430	581
5th A	A	G	C·3	432	$39\frac{5}{16}$	$2\frac{3}{4}$	0·700	1234	569
6th B	A♯·4	C♯·9		465	$35\frac{3}{4}$	$2\frac{11}{16}$	0·754	1019	525
7th C♯	C·1	E		511	$34\frac{9}{16}$	$2\frac{1}{2}$	0·724	912	582
Treble D	C♯·9	F	E	573	$33\frac{7}{16}$	$2\frac{9}{16}$	0·767	863	597
Extra C	B·1	D·7	A♯	483	$33\frac{3}{8}$	$2\frac{3}{8}$	0·714	820	539

Total, 12,798 lbs.

With the kind assistance of the organist of the church, Mr. D. D. Wood, I was enabled to get the upper partials of each bell very correctly in this peal. The numbers in the columns *Fundamental* and *Partials* mean decimals of half a note; for instance, F·8 means that

the note is eight-tenths of half a note above F, which makes it nearly F♯.

Price of the nine bells, ...	$4,095 36
Charge for hanging, ...	275 00
Total cost, . . .	$4,370 36

There is no sign of the bells having been chipped or turned for toning; but, judging from the timbre of some of the bells, it is presumed that they have been toned by the process of annealing or tempering.

The pitch of the peal is the same as the English scientific pitch, which is nearly half a note lower than Steinway's standard pitch used in this country as concert pitch, particularly by Thomas.

The peal is intended to be harmonically intonated, and to ring in two different keys, namely, in D and G. For the actual intonation it is best suited for the key of G, but the bell intended for C♯ should then be used as C.

The St. Stephen's Church has two towers, one north and one south of the main entrance on Tenth street. The peal is hung in the south tower, and in the north tower is an old but very good bell, cast for the Church in the year 1823, by John Willbanks, who then carried on bell-founding in Shoemaker street below Eighth, in this city.

The well-known bell-founder, Mr. Joseph Bernhard, learned the trade with Willbank and started his own foundry in Market street about the year 1845, and moved to 120 North Sixth street in 1852, where he cast many of the best church bells now rung in Philadelphia.

The first bell constructed by the writer for the U. S. Government, in 1855, was cast by Mr. Bernhard.

Peal of the Holy Trinity Church.

The Church of the Holy Trinity, corner of Nineteenth and Walnut streets, has ordered a peal of eighteen bells from Belgium, which is to be rung by electro-magnetism and expected to be in operation before the end of this year.

Great efforts were made to procure the order for this peal and having the bells cast in Philadelphia, but all in vain. Rev. W. N. McVickar, rector of the Holy Trinity Church, went to Europe in the spring of 1880 and visited several bell-foundries, evidently with the intention of selecting the best place for casting his proposed peal. The

peculiar sweetness of the Belgian bells induced Rev. McVickar to recommend them at home, and it was decided to have the chime cast at a foundry of wide reputation near Ghent. The order for the peal was given in December, 1880, and expected to be finished and rung at Christmas, 1881. Joseph E. Temple, Esq., presents the peal to the Holy Trinity Church, and it was at first intended to have twenty-five bells of two octaves chromatic scale, to be rung by electro-magnetism, operated on a key-board, all offered to be made complete in Philadelphia for $10,000, and ready for service at Christmas, 1880.

Centennial Chime.

The Centennial chime of thirteen bells, hung in Machinery Hall, and which rung in the Centennial Exhibition at sunrise on the 10th of May, 1876, was cast by Henry McShane, of Baltimore, at a cost of $10,000. The whole peal weighed about 21,000 pounds, of which the tenor weighed 4,000 and treble 300 pounds.

After the Exhibition was over, Mrs. A T. Stewart, of New York, bought this peal for the Cathedral at Garden City, Long Island, where it was tried to ring the bells with electro-magnetism, but did not succeed.

The tenor is hung to swing, the others are hung stationary and only the clappers swung.

Bell-Foundries.

The writer has visited many large bell-foundries in Europe, and examined all the most important old bells, and has come to the conclusion that the art of bell-founding has had its *ups* and *downs*, that better bells were made a century ago than now (provided the bells do not improve by age), and that bell-founding is now carried on more as a trade than as an art. The writer had an argument with a Russian bell-founder, in Moscow, about the construction of bells, and suggested that the form of the bell, the composition of the metal, and the moulding and casting should be made so and so, which would make the bell of a much better sound.

"Sound!" scouted the bell-founder, who was a man of practical experience.

"We do not care about the sound,
We sell the bell by the pound.
The sound don't weigh anything,
But is only heard when the bells ring."

The rhyming part of the above is accidental with English orthography, for in the Russian language it was only prose.

To value ringing bells per pound of weight is equivalent to the valuation of oil paintings per square foot of canvas covered. A bell should be valued by quality and volume of its sound, like a painting which is valued by art.

Sir Edmund Beckett says (page 325, book 21,252 Philadelphia Library, or book 509 Franklin Institute Library), "The Mearses, for a good many years, had the monopoly of church-bell-founding, with the usual result of monopolies, for they have turned out some wonderfully bad ones, though their predecessors in the last century and the early part of this made some famous peals."

The largest peal of bells in this country was made by the Mearses a few years ago, and now hang in the tower of St. Mary's Church, Burlington, N. J., which is said by competent judges to be the finest peal they have heard. Its tenor weighs 2,544 pounds.

Mr. Wm. Brown, the celebrated bell-ringer at St. Stephen's Church, says that the peal at Christ Church is the finest in Philadelphia.

For obvious reasons, the writer must abstain from making comments upon or compare merits or demerits of the different peals, but will only give the data from which any one conversant with the subject can form his own conclusion.

Bradford Peal, England.

The largest peal in England was cast by Taylor, in 1873, and hung in the tower of the Bradford town hall. It consists of 13 bells in the key of A, as follows:

The peal is intended to be harmonically intonated and to ring in two different keys, namely, in A and D. There are not sufficient data recorded for determining the *timbre* and other properties of this peal.

The second peal, in size, in England is that in the Cathedral of St. Paul, cast by Taylor in 1878, consisting of 12 bells with tenor 6,944 pounds.

The third in size is at Exeter Cathedral, which peal weighs 29,196, of which the tenor is 7,552 pounds. The Exeter peal was cast in 1676. The recorded data are not sufficient for analyzing the properties of this peal.

Dimensions of the Bradford Peal.

Intended Keynote.	Diameter. Inches.	Weight. Pounds.
Tenor A	$77\frac{1}{4}$	9,744
2d B	67	6,664
3d C♯	$59\frac{3}{8}$	4,657
4th D	56	4,266
5th E	50	2,720
6th F♯	$45\frac{5}{8}$	2,114
7th G	$43\frac{1}{2}$	1,789
8th G♯	$41\frac{1}{2}$	1,563
9th A	$39\frac{1}{2}$	1,420
10th B	$35\frac{1}{2}$	1,030
11th C♯	$33\frac{3}{4}$	969
12th D	33	907
Treble E	$30\frac{3}{4}$	870

Total, 38,713 pounds.

Timbre.

When the composition of the bell-metal is 31 weights of tin to 100 weights of copper, the timbre of the best bells is generally 580. The more the timbre varies above or below that number, the worse is the bell.

The great bell cast by Taylor for St. Paul's, in 1881, has a timbre of exactly 580.

Worcester Peal, England.

The fourth peal, in size, in England is that at Worcester Cathedral,

consisting of 13 bells cast by Taylor in 1869, of the following dimensions:

Intended Keynote.	Diameter. Inches.	Soundbow. Inches.	Soundbow. Strokes.	Weight. Pounds.	Timbre.
Tenor D♭	63·	4·8	0·78	5,600	563
2d E♭	56·	4·07	0·726	3,944	588
3d F	50·4	3·7	0·734	2,948	587
4th G♭	47·25	3·44	0·729	2,419	587
5th A♭	42·5	3·1	0·729	1,736	585
6th B♭	38·5	3·	0·780	1,344	562
7th C	36·	3·	0·833	1,256	554
8th D♭	35·	2·9	0·829	1,169	573
9th D	34·	2·9	0·854	1,068	573
10th E♭	32·5	2·8	0·863	980	574
11th F	30·5	2·7	0·885	878	580
12th G♭	29·5	2·44	0·830	806	644
Treble A♭	28·	3·	1·070	775	533

Total, 24,923 pounds.

The peal is intended to be harmonically intonated and to play in two keys, namely, D♭ and G♭.

Effect of Bad and Good Bells.

The ringing of a peal of bad bells is a detestable nuisance, which should never be allowed to disturb the peace and solemnity of the Sabbath, and causing, as it does, sufferings to those of sensitive ears

who may unfortunately be within earshot of that noise. They say about the bell-ringers

"Disturbers of the human race,
Your bells are always ringing.
We wish the ropes were round your necks
And you upon them swinging."

On the other hand, when we hear

"A chime of good bells,
How many a tale their music tells,
Of youth, and home, and that sweet time
When first we heard their soothing chime."—MOORE.

ERRATUM.—In the article on "Bells," in the preceding number of the JOURNAL, the word *treble* is printed *triple*.

ELECTRIC CLOCKS AND TIME TELEGRAPHS.

By LOUIS H. SPELLIER.

[Abstract of a Paper read at the Stated Meeting of the Franklin Institute, May 17, 1882.]

Two years ago I read a paper before the Institute on the subject of "Electro-magnetic Time Telegraphs," or electric clocks that receive the time telegraphed in certain intervals from a weight or spring clock.

I then stated that "they mainly depend upon the action of one electro-magnet and one armature." The latter is a piece of iron which is attracted by the poles of the electro-magnet, when the telegraphing clock completes the circuit of a galvanic battery connected with it. As soon as the clock breaks the circuit again, the armature is repelled to its former position by a spring or weight. This movement of the armature turns a wheel which drives time-indicating machinery, and is repeated as often as this machinery requires to indicate the time of the clock, which makes or breaks the electric circuit.

Such instruments work very well, if the action of the armature is needed about once every minute, but if repeated every second or two, then its imperfections become apparent. The movement of the armature is sudden and rapid. With a lightning-like velocity the armature moves toward the magnet, and is checked instantaneously in its rapid progress just at a time when nearest to the magnet and most powerfully

attracted. Naturally the wheel, which receives its impulse directly from the armature, moves with the same rapidity and is checked as suddenly. These sudden checks, offered to the armature and wheel, show their damaging results in a short time, and soon impair the correctness of such instruments.

These clocks, as a rule, soon get out of repair, as may be seen by those in use at the Pennsylvania Railroad Depot in this city. Their noise resembles that of a hammer striking forcibly upon an anvil and it is only surprising that they run as long as they do.

To meet the above-mentioned faults of electric clocks is the purpose of the device of my electro-magnetic escapement, of which I exhibited

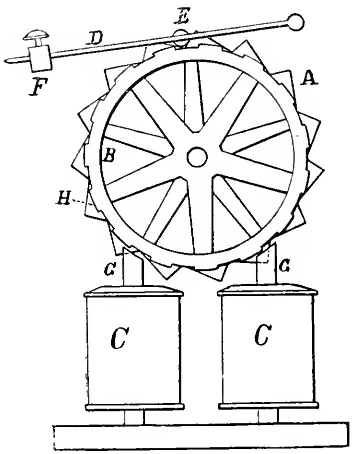


Fig. 1.

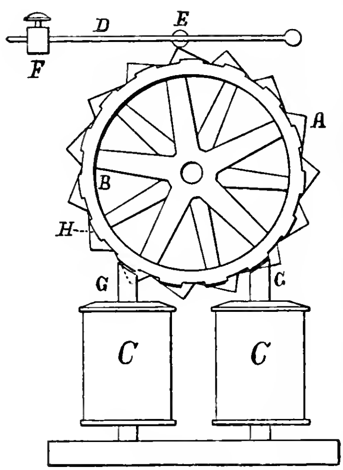


Fig. 2.

here my first model about two years ago, and which is, indeed, the only second system of time telegraphs that is new in its fundamental principle that has been invented in almost half a century.

With the aid of the accompanying cuts, Figs. 1 and 2, which show the principle of my electro-magnetic escapement in its two main positions, I will be able to explain the manner in which I have corrected these evils by the invention of my system. Referring then to Figs. 1 and 2, *G* is the electro-magnet, *B* is an iron wheel that has on its circumference the projections *H*. Those projections are armatures. Fastened to the same axle with this iron wheel is the escape wheel *A*, with the peculiarly shaped cog shown in the drawing. *D* is a lever

with an adjustable weight at F, and presses by means of the pulley E on its circumference and rests at the bottom of the cog, when the electro-magnet is not charged with magnetism. When in that position, as shown by the drawing to the left, two of the armatures are very near to the poles of the electro-magnet.

At the moment when the electric current passes through the coil C, and the poles G become magnetized, the two armatures will be attracted and take their position right over the poles of the electro-magnet as shown by the drawing to the right.

The escape wheel A fastened to the same axle with B has moved with it and lifted up the lever D, and has in its movement gone so far as to allow the pulley E to glide over the point of the cog and keep its position, shown on the drawing to the right, until the electric circuit is broken again; then the poles G become demagnetized, the armatures are no longer attracted, and the wheels A and B move under the pressure of the pulley until it has reached the bottom of the cog. By this movement the next succeeding two armatures have taken their position shown to the left, again ready to be attracted at the next closing of the electric current. In this manner is produced, by alternately opening and closing the circuit, a step-like movement of A and B. You will perceive that the object aimed at to avoid violent checks of the armature is completely achieved. Another advantage of no less significance is gained, namely, that it is impossible for the escape-wheel to move without an extra provision, at any given impulse, more than one cog.

Before I show the application of my escapement to time telegraphs I will explain the manner in which I make and break the circuit by means of a weight clock, in order to transmit the time to the electro-magnetic escapement. This current-breaker, Plate I, Fig. 1, I have found to be very effective. B is a metal disk fastened to the axle of the escape-wheel of a clock. It has platinum pins vertically upon its face. C is another smaller platinum disk fastened to the pin-bearing disk, b and b' are two springs with platinum terminations. The spring b rests on the platinum disk, while b' forms the contact with the platinum pins.

When the disk moves with the escape-wheel of the clock it will complete the circuit of the galvanic battery, whenever the spring b' comes in contact with one of the pins, and when the spring is removed from the pin, the circuit is broken.

I found this current breaker fully to answer its purpose and to meet

all the requirements. It prevents by means of friction all accumulation of dust and oxidation and keeps the contact surface bright.

The best clocks for making the contact for time telegraphs are undoubtedly those provided with a gravity escapement invented by Edmund Becket. Clocks with gravity escapements allow an increase in the weight of the clock to such an extent as is needed for a secure metallic connection of this contact-breaker without affecting perceptibly the impulse given to the pendulum.

I will now show the construction of my time telegraphs for two different purposes; one kind is intended for different apartments of any building, and the other for public clocks only.

Of the first-mentioned clock I have six in operation here in our lecture-room, and their construction is shown in Figs. 1 and 2, Plate II. This is the clock with a centre or sweeping second-hand, of which I possess but one specimen. The figures show a front and side view of it, and it will at once be recognized that *GC* is the electro-magnet, *A* the escape-wheel, and *B* the iron wheel with its projecting armatures. *D* is the pressing lever with its pulley *E*, and *F* the adjustable weight.

It is unnecessary to explain the action of the escapement again, nor to explain the purpose of every wheel, but I will merely state that *H* is the wheel that carries the hour hand, *M* the minute hand, and *S*, the extended pivot of the escape-wheel axle, is to receive the second-hand.

The electric current acts in these clocks once in every *four* seconds, and if the duration of the current is that of two seconds, the second-hand will execute the movements of a clock provided with a two second-beating pendulum. If, however, the circuit is closed once in four seconds for a time just long enough to allow the attracted armatures to take their proper position over the poles of the magnet, for which a fraction of a second is fully sufficient, it is evident that a great saving of electrical force is gained, and the battery employed will need a less frequent attention. The duration of the current can be easily regulated by adjusting the contact spring b' of the current-breaker. If the spring is set more or less deeply into the circle of the contact-pins, a contact of longer or shorter duration between spring and pins will be effected accordingly. The escape-wheel has a diameter of two and three-eighths inches, while that of the armatures has a diameter of two and one-eighth inches. The dial of the clock has a diameter of two feet. It can be made, however, two feet and a half

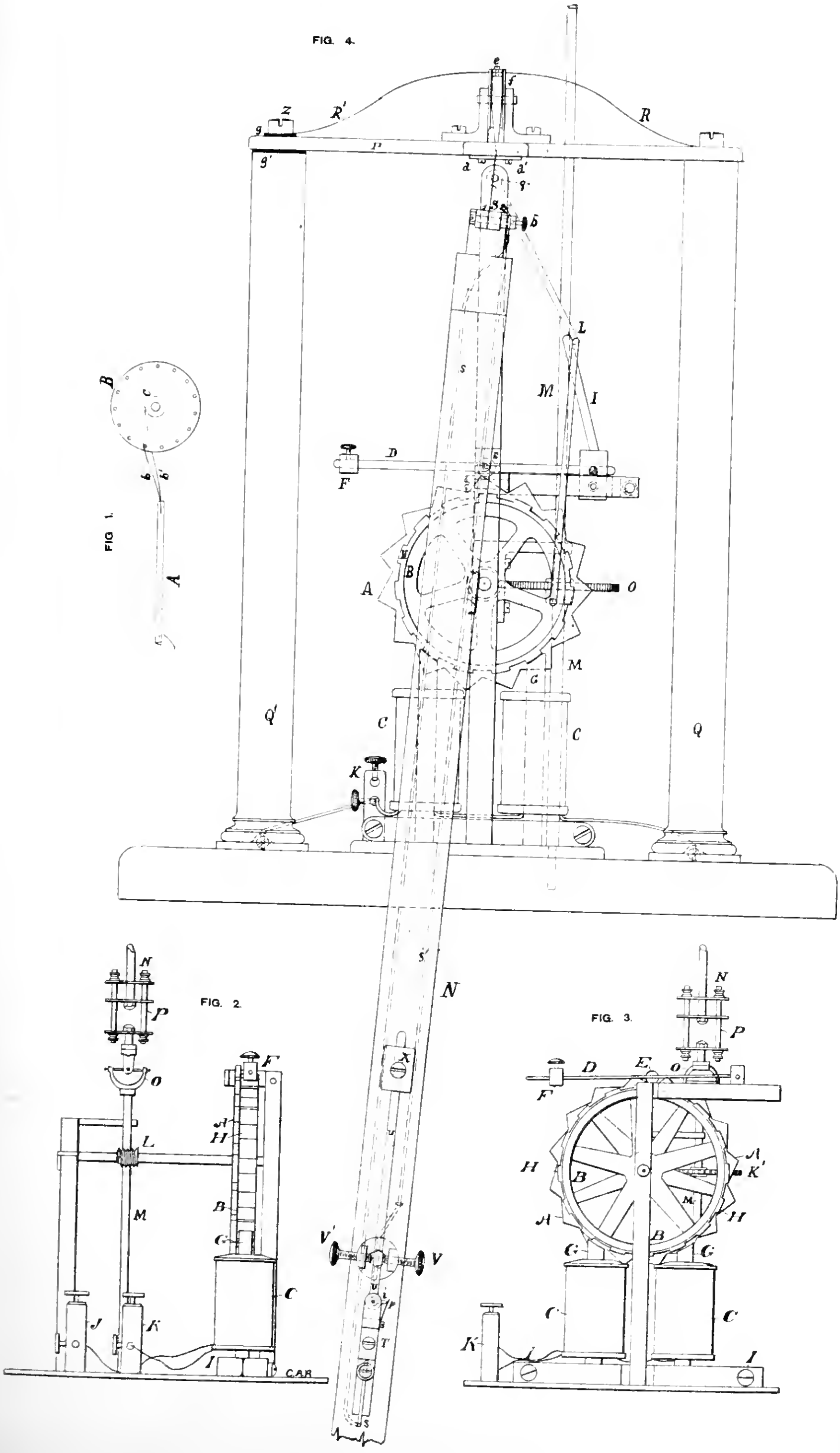


FIG. 4.
e
f
Z
R'
R
g
g'
P
d
d'
q
b
L
M
I
S
D
F
A
B
O
M
G
C
C
Q'
Q
K
S'
N
X
V'
V
T
FIG 1.
B
C
b
b'
A
FIG. 2.
N
P
O
F
L
A
H
M
B
G
C
J
K
I
CAR
FIG. 3.
N
P
D
E
O
F
H
B
A
K'
M
H
G
G
C
C
K
I

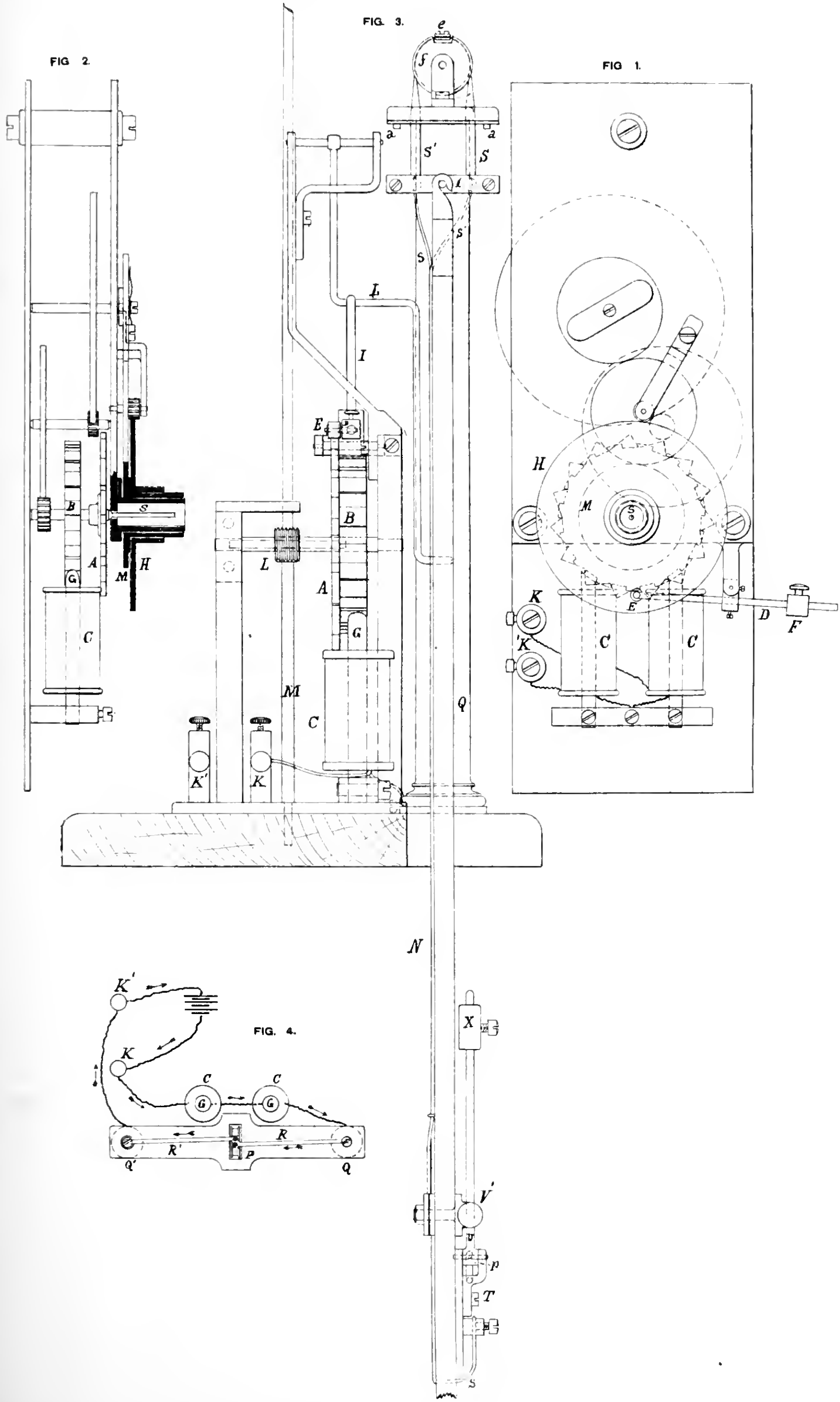


FIG 2.
FIG. 3.
FIG 1.
FIG. 4.
B
S
A
G
M
H
C
e
f
a
a
S'
S
s'
s
L
I
E
K'
K
Q
N
X
V'
p
T
D
F
R
R'
P
Q'

without overtaxing the small escapement with more work than it can perform.

I have been running two of these clocks with one calland. To make it secure, however, one calland should be used for each clock. The clocks run very easily and lightly. I direct attention on this point to the clock with centre second-hand here in operation. In order to perceive its beat, it is necessary to bring the ear close to it, when a muffled pulsating sound will be perceived. In this respect my time telegraphs are in striking contrast with those of the old system.

While the latter are the most noisy clocks ever made, mine will prove to be the most noiseless of any clocks invented for their size, the pneumatic clocks, perhaps, excepted,—an advantage very desirable in hospitals, where the very tick of a clock in a sick room will annoy the nervous patient.

I have made the escape-wheels of hard rubber or vulcanized fibre, which makes them very light and easily movable.

The fact that second-beating time telegraphs have been of such a self-destructive nature has driven them almost entirely out of use. In some of the principal cities of Europe electrical clocks are quite common, but the mode of moving the hands once in a minute is generally adopted. This is the case, for example, with the very perfectly arranged series of clocks in the city of Geneva, built at the expense of the city government, and constructed by the eminent electrician, Dr. Hipp. There the time is telegraphed every minute to the watch and clock makers of the city from the astronomical observatory.

The necessity, therefore, of moving the hands once in a minute instead of every second (in order to avoid the early destruction of the mechanism) is avoided by the invention of my escapement, since it moves as lightly as the escapement of any weight or spring clock, and I think with its application a successful future is secured for the time telegraph. If time telegraphs are once made a success, then their advantages are too apparent to need much demonstration. Good timepieces are exceedingly costly. The city of Paris, which adopted the mode of setting ordinary spring or weight clocks throughout the city through the medium of electricity, has paid for the thirteen clocks employed to do that work from $450 to $500 each.

Institutions that desire correct time in every room of their buildings,

may have it wherever it is desired at a comparatively small expense with one good clock and the use of a well-working time telegraph.

But there is still another field open in which a successful time telegraph can be of great service to the public in general; I mean its application to public clocks of any dimensions. "It has become a problem of great perplexity to this day with the most ingenious minds of the horological world to construct clocks which will overcome the effects of wind and storm beating against the exposed clock dials of public clocks, forcing the hands in one or other direction; and here I think it is that the time telegraph has its future. A good and well-regulated clock, kept at a place of no great change of temperature, will show but very little variation in time. If such a clock controls a time telegraph adapted for tower and other public clocks, it will show the time with only such slight variation as will hardly be noticed by the public."

I have constructed time telegraphs for this purpose and I think with full success. Not very long ago one of our daily papers stated that the reason why they had not an electric clock in the tower of the new building of the Pennsylvania Railroad depot was, that they could not get an electro-magnet strong enough to move the hands! There are plenty of electro-magnets strong enough to do it, but they had no electric clocks of such construction as to answer the purpose.

I have here a time telegraph constructed for the purpose of indicating time on public clocks. It is not large enough to fill a good size pocket, and yet almost sufficient to do the very work. They could not find an electro-magnet powerful enough, and yet the electro-magnet of this instrument I have here is rather small. The diameter of its iron core is but five-sixteenths of an inch, and the escape-wheel belonging to it is only three inches and a quarter in diameter. It is only necessary to add one-third to its size in order to make it of sufficient strength to do the work required of the clock in the tower of the Pennsylvania Railroad depot. A time telegraph for public purposes is here in operation and may be examined after the meeting. Its construction is shown in Plate I, Figs. 2 and 3.

The escapement will be readily recognized, and but very few words will be needed to explain its operation. Fig. 2 shows a side and Fig. 3 a front view. The side view will show that escape-wheel A and that of the armature are closely fitted together. The axle has a screw at L that moves the wheel K on the upright standing axle M forming

with K an endless screw; if we now connect the axle M with the shaft N leading to the dial works of a clock dial you will readily understand that all that is now necessary is to make and break the electric circuit connected with the time telegraph and the electric battery as often as is needed for the proper movement of the clock hands.

I have now shown the application of my electro-magnetic escapement on time telegraphs, and I will close that subject by reading to you the opinion given in a report of the Committee on Science and the Arts of this Institute, to whom my escapement was referred for examination. On the merits of the escapement the report reads as follows:

"The principal object we think worthy of commendation is the very ingenious escapement which entirely avoids any sudden jar (for there is no impact) and works smoothly and noiselessly and practically with the least possible friction.

"Believing that the time is not far distant when it will be necessary to transmit time from a standard clock to different points in a large city, or in hotels, factories or dwelling houses, there are no means by which it can be done as cheaply, quickly and accurately as by electricity, and there is no device that promises to do it so well, that we have yet seen, as Spellier's Electro-magnetic Time Telegraph. As we think Spellier's invention such a great step in advance that it merits the warm approval and commendation of the Franklin Institute, we recommend that he be awarded the Elliot Cresson Gold Medal;"—and I hope the result of my efforts has vindicated their anticipations.

I now come to a subject of less general interest, but of not less importance, that of real electric clocks, where the moving power of the whole mechanism is electro-magnetism only. I called such clocks in my paper two years ago more of a scientific curiosity than a useful invention; and yet some of the most prominent philosophers and mechanicians have devoted their time and genius to their construction to make them correct time-pieces. The first who constructed such clocks was Bain, about 45 years ago. At present the clocks of Dr. Hipp seem to take the lead, but although he claims great accuracy for them, they seem not to sustain the claim in every instance. One small specimen of his clocks is exhibited in the window of Mr. Thomas Shaw, Ridge avenue, above Ninth street, of our city. In principle I think it to be a step backwards, as it is but a modified and improved clock of the Bain type.

There are three main difficulties in the way of making electric pendulum clocks a success.

They are, first, the variation of the strength of the electric current of galvanic batteries; second, the danger that the current-breaker will not make a sufficiently secure contact for the passage of the electric current, since the contact is made by the pendulum, which has not in all cases sufficient surplus of power to make a secure contact; and, third, the obstruction which the current-breaker offers to the pendulum in its oscillations. Therefore, electric clocks can only be a success when the above-mentioned difficulties are avoided. I think I have met the difficulties successfully by a clock exhibited here to-night, presently to be explained.

I shall first explain the current-breaker of my clock, and to show how far it differs from those employed up to this day I will introduce this explanation by a brief description of the current-breaker now in use at the astronomical observatory in Paris.

There the pendulum of the clock has two side-extending metal arms. Each of these arms is provided with three screws with platinum terminations. Three levers, separately movable, but in metallic connection, corresponding to the screws, will be either in contact with, or removed from the screws as the pendulum moves to and fro. The levers and the arms are inserted into the circuit of a galvanic battery and an opening and closing of the same, corresponding to the oscillations of the pendulum, will be effected. That the pendulum meets with a comparatively great obstruction in its movement by such a current-breaker cannot well be disputed, and yet the contact cannot be formed with a great deal of force to make it as secure as desired, since the levers have to be very light so that they will not obstruct the pendulum too much in its movements.

I now will show how I effect with a new device of a current-breaker a secure and firm contact, and yet at the same time allow the pendulum to follow the course of its oscillations without meeting with any obstruction. Plate I, Fig. 4, shows a front view of my electric clock, and Plate II, Fig. 3, a side view, in which *N* is the pendulum and *T*, *V* and *V′* its current-breaker. You see an upright standing lever, *U*, with a weight *X* on the top. Near its fulcrum are two screws *V V′*, against the one or the other the lever will rest, if the pendulum is out of its vertical position to one side or the other. Two electric wires, *s s′*, coming down the pendulum rod are in metallic connection with

the two suspension-springs S S' ; both springs are fastened together at c' by an insulated substance, and each of these suspension-springs is again connected with its corresponding spring R R'. Now let the poles of the galvanic battery be connected with the springs R R', and set the pendulum oscillating. If the pendulum has its present position, the lever U rests rgainst the screw V, and forms a metallic contact with the screw. The screw is connected with one of the wires coming down the pendulum rod from one of the suspension-springs, and the lever is again connected with the other wire coming from the other suspension-spring, so that the electric current can pass through the contact made by the lever U and the screw V. If the pendulum has its position on the opposite side, the lever will bear against the screw V'. This screw has an insulating substance upon its termination that keeps the circuit broken. Thus, by the movements of the pendulum to and fro the lever U will bear against one or the other screw and make and break the electric circuit. The fall of the lever from one to the other screw is so small that it needs very careful watching to perceive it. The contact formed proves to be secure. It is made with a great deal of force, since it is formed very near the fulcrum of the lever. You will observe that this simple contrivance of my current-breaker removes two of the principal difficulties which electric clocks have to combat with. It now remains to show how I made the impulse given to the pendulum for its movements independent of the strength of the electric current acting upon the electro-magnet of the clock. The springs R R' are connected with the electro-magnet and inserted into the circuit of the galvanic battery. You see in the drawing fastened to the axle of the lever D that moves the escape-wheel, an arm I. Against this arm rests the lever L with its fulcrum at q. The extension of this lever touches the pendulum, while resting on the arm I, when the pendulum hangs in its vertical position.

Now if the pendulum is moved to the left, as it is shown in Plate I, the lever of the current-breaker will bear against the screw V, and close the circuit. The armatures nearest to the magnet are attracted, and the lever D that moves the escape-wheel is raised, and with it the arm I is moved, which in turn raises the lever L; there it remains until the pendulum has taken its position to the right. Then the lever of the current-breaker drops against the insulated screw V', and the circuit is broken, then the lever D suddenly drops down, moving the escape-wheel, while the lever L drops against the pendulum and the

pressure of its weight gives the pendulum the impulse for its oscillations. This action of the mechanism is repeated as the pendulum swings to and fro. If we now consider that the lever is always lifted up to the same height, and its weight is not subjected to any changes, the power, acting upon the pendulum to keep up its oscillations, must be the same at every impulse given, without regard to the attracting force of the electro-magnet. It will be seen that this electric clock makes a firm contact for the electric current to pass; and that it does not obstruct the pendulum in the course of its movements, and also that it makes the movements of the pendulum independent of the strength of the galvanic current. This, I think, embraces all the elements necessary for a true time-piece.

Some few words are in place regarding some details of the clock, to make the entire mechanism understood.

Two hard rubber plates, g and g' are essential to insulate the metal plate P from the screw Z and the post Q, to prevent the current from going directly through the plate P from Q to Q', in which case the current would escape the passage through the current-breaker, and the circuit would be continuously closed.

To avoid the passage of the current through the holes in which the pivots of the lever U move, a spring, p, is fastened to the support of the lever, pressing against a platinum pin, i, at the axle of the lever.

The pendulum suspension of this clock is made according to the principle of my suspension as described in the JOURNAL OF THE FRANKLIN INSTITUTE for July, 1880, to which I must refer for its object and detailed construction. Here it is necessary to state that the pulley f, over which the suspension-springs S S' are laid, is of hard rubber, to keep the springs insulated. 1 and 2 are two bars, also of hard rubber, which support the pendulum, and between which the two ends of the suspension-springs are fastened. The plates a and a' are of the same material and are used to hold the suspension-springs in their proper positions.

The clock, shown in the plates, has an escapement of the same dimensions as the time telegraph for public clocks already described, and is otherwise like it in all its details. It is the first one built, and mainly made to establish its principle. I had attached to it four dials, three feet in diameter, with a battery of three callauds. They can, of course, be made of very small dimensions, and will then require but little battery power to keep them going.

The course of the electric current is indicated by the arrows on the ground plan, Fig. 4, seen below the side view in Plate II.

Now, a few words in conclusion, of the utility of the electric clocks, before I close. They will hardly ever come into general use, and always be a costly novelty for those who desire to have them. If we, however, succeed in constructing correct electric time-pieces, they may become of great value in astronomical observations. The astronomer, while making his observations, listens to the beats of his pendulum clock. The beats of an electric clock are louder and more perceptible than weight clocks, and therefore, more desirable, if correct. But that is not all. We know that the density of the atmosphere is subject to constant changes. The resistance of the pendulum, therefore, through the air will vary with its density, and so disturb, although slightly, the regularity of its movements. This can be avoided with electric clocks by closing them in hermetically closed glass cases with greatly rarified air, and, indeed, a great many clocks exhibited at the last Paris Exposition were provided with this precaution. Among others, those of Dr. Hipp were most numerously represented, but since the barometrical error of pendulum clocks is so slight, and the oscillations of the pendulum on Hipp's clocks not only are greatly obstructed by his manner of forming the contact (although admirably ingenious), but still more by the fact that his pendulum works in reversed order (moving the clock train), it is hard to see how the removal of the slight barometrical error will compensate for the faults his clocks are subject to; unless it is taken as a suggestion for a more perfect clock for the future. There is certainly plenty of reasons for the doubtful reception these clocks have received at the hands of some of our prominent philosophers, and of which Dr. Hipp so greatly complains.*

The perfection of electric clocks, however, should receive its full share of attention and encouragement, for the service they may render at astronomical observatories, for reasons already stated. But such work should not be expected from the enterprise of individuals. It properly belongs to the government, which should always furnish the standards for the use of all the people.

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* See *Electrotechnische Zeitschrift*: Berlin, 1881, page 102.

FELDSPAR AS A SOURCE OF POTASH ALUM.*

By John Spiller.

The aim and object of this Society, as I understand them, will be not only to record the steps of progress made in actual chemical manufacture, but to take account of "wasted ingredients," with a view to their possible economization in the future. It is under this latter head that I beg leave to offer a few suggestions bearing on the manufacture of alum, which have been sufficiently confirmed by laboratory work to prove my case, although I do not pretend to have turned them as yet to practical account.

Starting from feldspar and the large class of rocks in which it is contained, such as granite, gneiss, porphyry, syenite, green-stone, mica-slate, and the basaltic rocks which together constitute a large proportion of the earth's surface, we find a mineral occurring which contains *more potash and alumina* than is present in common alum. Every chemist knows of the methods of decomposing silicates in mineral analysis by attacking them with hydrofluoric acid; but as it was my object to prepare a *sulphate*, and to work as cheaply as possible, I employed a mixture of fluorspar, feldspar, and sulphuric acid. Alum is formed, together with calcium sulphate, and the gaseous fluoride of silicon. The last named gas, passed into water, gives a finely-divided silica, most useful as polishing powder, and hydrofluosilicic acid, for which there is already occasional use in the arts. Comparing now the percentage composition of feldspar and alum, and taking for the former the mean of three analyses, published by Watts, we get for common Feldspar, "orthoclose."

	Alumina.	Potash.
Stolberg (Rammelsberg),	16·98	14·42
Lomnitz (Valentine Rose),	17·50	1·200
Chomounix (Delesse),	19·06	10.52
Mean	17·85	12·31

or together, say over 30 per cent. of ingredients useful in the manufecture of alum, which salt, when crystallized, contains only 10·83 per

*Journal of the Society of Chemical Industry, April, 1882.

cent. of alumina, and 9·91 per cent. of potash, or 26·74 per cent. of total bases. This looks hopeful from a manufacturer's point of view, for, taking the potash as regulating the yield, 100 parts of feldspar should give nearly 124 parts of crystallized alum, and if the relative deficiency of alkali were supplied, then the yield (calculated from alumina) should be as high as 165 per cent.

In my own experiments I have not succeeded in getting more than an *equal weight*, but I have been working under disadvantage with samples of colored feldspar, containing a considerable quantity of iron. From a piece of white granite I have obtained a fair quantity of alum with very much less iron in solution; and to this point I had arrived when my attention was directed to a previous publication of the fundamental fact in the "Bulletin de la Société Chemique de Paris" for June 7, 1872. The particulars are as follows: At the Paris meeting M. Lecoq de Boisbaudran was describing a process for the extraction of cæsium and rubidium from lepidolite. He attacks the mineral with hydrofluoric acid, and separates the rubidium and cæsium by taking advantage of the difference of solubility of the bi-tartrates. Then M. Guignet, in the discussion, says he "thought it might be possible for this extraction to utilize the action of *sulphuric* acid, and separate the alkalies in the state of alums, this proceeding having been used by him to extract the potash from feldspars." The brief terms of this report (three lines only) do not afford much information, or make it clear that M. Guignet ever worked with a mixture of feldspar and fluor-spar, but he evidently aimed at economizing the potash in feldspar, and may have succeeded in so doing.

Reverting now to my own experimental results, two or three points of practical interest may be mentioned.

1. I find it necessary to get rid of the excess of sulphuric acid by thoroughly heating the decomposed mass in a current of air before dissolving, on account of the extraordinary increase of solubility of alum in acid liquors.

2. When granite is attacked by nascent HF, the feldspar and mica disappear long before the admixed quartz, most of the latter remaining the residue.

3. The employment of sheet-lead vessels is not be recommended, for the cost is great and the low fusion point of the metal restricts too much the degree of temperature which it is needful to apply in order to expedite the decomposition.

When the treatment is successfully accomplished there is the large amount of calcium sulphate to be dealt with, left as a bulky residue on treating with water. It struck me, therefore, that it would be more advantageous to use the mineral cryolite ($3NaF,Al_2F_3$), which is so plentiful in Greenland, in place of fluorspar as previously described. This would augment the amount of aluminic sulphate formed at the same time that it supplied the needful fluoride. Here, again, Persoz, Sauerwein, Thomson and others have described the manufacture of crude alumina salts from cryolite *per se*, but none of these processes include the idea of making the hydrofluoric acid available for decomposing the native double silicates of potassium and aluminium mixed therewith. The relative proportions in which the feldspar rock and cryolite have to be employed, as also the amount of sulphuric acid required, must be dependent upon the nature of the rock operated upon, the amount of admixed quartz, etc., and could be easily determined by making a few preliminary experiments upon a fair average sample of the rock about to be treated. A warm hearth, made slightly hollow, and lined with fire-bricks, or slabs of the rock itself, gently heated by reverberatory action, will probably be the best construction for conducting the operation on a manufacturing scale.

Next, as to the varieties of granite and porphyry which are likely to yield the highest percentages of potash, there are displayed in the Museum of Practical Geology about a hundred polished samples, which I have lately been to inspect. Amongst these I find that the granite, from the Duke of Argyll's quarries in Mull, appears to consist almost entirely of rose-colored feldspar. The blocks from the Mourne mountains, county Down, are mostly white feldspar; and large crystals of the same are seen in the white granites from Lanlivery (Cornwall), St. Barule (Isle of Man), and the specimens from Castlean (near Penzance), and Lundy Island. Rubislaw and Cove (Aberdeen) produce almost pure feldspar, containing 13 per cent. of potash. Peterhead granite is rich in feldspar, but it is highly colored with ferric oxide.

The whole subject appears, therefore, well worthy of extended investigation, and, as the American potashes have been dsiplaced to a great extent by the Stassfurt salts, so in time it may chance that British sources of potash will take the place of the German supplies.

ON THE PREVENTION OF FIRES IN THEATRES.

By C. John Hexamer.

[A paper read at the Stated Meeting of the Franklin Institute, held June 21, 1882.]

Since the beginning of this century estates worth over one hundred million dollars, and thousands of lives, have been destroyed by theatre fires, while thousands of others were fortunately saved from the same fate.

First, as to the number of theatres in general: Europe contains 1486 theatres, of which France has 337; Italy, 296; Spain, 168; Great Britain, 164; and Austria, 152. The United States have 557 (about). Paris has 40; London, 32; New York, 21; Naples and Milan, 31 each; Philadelphia, 12; and Rome, Turin, and Brussels, each 10.*

Comparing the number of theatres with the populations, we find the following ratios:

Italy,	one theatre for every			75,000	inhabitants.
United States,	"	"	"	90,000	"
Spain,	"	"	"	93,000	"
France,	"	"	"	110,000	"
Great Britain,	"	"	"	184,000	"
Austria,	"	"	"	235,000	"
Russia,	"	"	"	1,360,000	"
Turkey,	"	"	"	2,000,000	"

Theatre fires can have but two eventualities: either the fire is extinguished in the first minute, or the entire theatre destroyed. This is easily accounted for by the extraordinary danger, from fire, of our modern theatres.

In the large space called the stage (of which the audience sees comparatively little) we find immense masses of laths, boards, and other wood-work, which, by long heating, are entirely dry, and may, therefore, be instantly inflamed. Among these we find great quantities of gauze,

* The above statistics were taken several years ago. An article in the *Daily News* a short time ago, shows that London, at present, has 57 theatres, 408 music halls and 475 other places of amusement, which can, on the average, accommodate daily 302,000 persons. The average daily attendance at the theatres is about 126,000.

coarse canvas, and other easily inflammable goods. Furthermore, ropes, paper soaked in varnish, paste-board, etc., in short, a mass as readily inflammable as could well be found.

In the midst of these is the more or less well-arranged heating apparatus; also a great number of gas flames, each forming a dangerous sphere around itself.

The danger is still increased by these combustible materials not remaining stationary. They are let down, drawn up, shifted about, and are, therefore, more liable to come in contact with the gas flames. At times it is necessary to provide illuminating effects temporarily, as, for instance, where the chandelier of a ball-room scene, which is fed by a rubber hose, must be removed during change of scene.

We are particularly careful in places filled with combustible materials, to enter them with closed lanterns only, eschewing open lights and candles. On the stage, to the contrary, guns are fired off, torches swung, fireworks set off, while, at the same time, scenes of laths and canvas are let down, as, for example, in the last scene of "Sardanapalus." A German writer on this subject says: "One who has been behind the scenes during the performance of a spectacular piece, and found himself suddenly enveloped in a sea of fire, and has noticed how a force of men are engaged in extinguishing (by means of wet rags suspended on long poles) the sparks which have settled on the scenery; who has noticed how, notwithstanding all care, fiery objects fly from their prescribed course, or has seen how a piece of firework too strongly loaded throws everything into confusion; one who sees this for the first time cannot overcome the feelings of astonishment and fear; and this, when viewed from the audience, is no more than is common in spectacular pieces."

These circumstances, not taking into account criminal negligence, show how readily a stage may be set on fire; and how, if not extinguished immediately, or at most in the first minute, it must spread with immense rapidity and destroy the whole building. After this time the most strenuous efforts are futile. During such intense heat the, so called, fire-proof constructions become useless, the strongest walls are destroyed, marble is burnt into lime, cast iron disintegrates, wrought iron loses all tenacity, and the entire building is destroyed.

Of the number of theatre fires we have but a poor register. The writer has collected a list of some 150 theatres which have burnt down within the past 100 years. This table does not—although great care

was spent upon it—include, by any means, all of these disasters. With the news of a newly burnt theatre we generally get the notice that it had been built in place of one also destroyed by fire. So, for example, in London, the "Haymarket Theatre" was burnt in 1789 and 1867; the "Covent Garden Theatre" in 1808 and 1856; and "Astley's Amphitheatre" in 1794, 1830, and again in 1841. In London there have been, since 1772, not less than 18 total losses of theatres, and in Paris, 20.

It is, therefore, not too much to say, that destruction by fire is the natural end of theatres. In looking over a table of theatre fires we are struck by the rarity of such calamities in Italy.

The explanation of this fact is neither to be sought in the more solid mode of building, nor in any particular care or prudence of the Italians, but partly in the mild climate, making heating unnecessary, and partly in the character of their performances. The Italian, of all grades of society, seeks in the theatre not so much sensational and spectacular pieces, but he wishes foremost to hear music, and thus many dangers disappear. With our growing taste for spectacular pieces, the number of theatre fires must increase.

It has been found that more than half (52 per cent.) of all theatre fires occur from December until March; a fact easily explained by the use of heating apparatus, and by the production (especially in England) of Christmas spectacles.

The time of day at which such fires occur is a consideration of great importance. It has been calculated that 13 per cent. of all theatre fires occur in day time, before, or during rehearsals, which are generally held by gaslight; 2 per cent. in the evening before the audience has entered; 21 per cent. during performances; 48 per cent. during the two hours following performances; and 16 per cent. later at night. The statement may excite surprise that nearly one-half of all theatre fires occur two hours after the performances, and that it is this period which is the most dangerous. It has been stated above that, in theatres, flames spread with lightning speed, but in case a spark has settled on a piece of canvas, it may glow for a long time unnoticed, until a sudden draft causes it to burst into flames. This cause, combined with the poor, or entirely neglected, watching of stages at night time explains this seemingly peculiar fact.

As before stated, in case of fire, theatres are always total losses, or, as it has been said: "It is a pity for every drop of water which, in such

a case, is used otherwise than for the protection of the surrounding buildings."

Of all the better known theatre fires, it has been found that 23 per cent. were isolated, and on this account the further spreading of the flames was impossible; 36 per cent. greatly endangered the surrounding buildings, and these were only saved by the most strenuous efforts; and 41 per cent. (nearly half) extended to other buildings. Theatres should, therefore, not expose other buildings.

In 1867 the fire at the "Haymarket Theatre," London, notwithstanding the greatest efforts, destroyed a great number of surrounding houses, making 400 persons homeless. The theatre fire at Cincinnati, 1866, caused the destruction of several of the largest banks, offices, and other buildings. The fire at the "Bowery Theatre," New York, 1867, spread throughout the entire block. In 1866 the fire at the "Academy of Music," New York, destroyed a church, an academy, with valuable collections, and many dwellings and factories. These few cases will suffice to show how necessary it is that theatres should not be connected with other buildings, and that they should be built on large lots.

That existing defects may be oviated and remedies proposed, it is necessary we should know (1) the cause of a theatre fire, and (2) where it originated.

The most frequent cause of fires is carelessness. An instructive example of this is afforded by the destruction by fire of the "Grand Opera House" at Dresden. With incredible carelessness, workmen had been ordered to repair some rubber hose with a benzine solution; the garret in which they worked being dark, they lighted it by candles. These inexperienced people carried on this dangerous business for some time, until at last, on the 21st of September, 1869, one of the workmen, in lighting a candle, lit the benzine on his hands, and at the same time some rags; in a short time the whole building was in flames, and totally destroyed. With such management, it may not excite surprise to learn that during the fire all water reservoirs were empty, and that the wire curtain was rusted fast, and could not be let down.

The question is frequently asked, "What can be done to diminish the combustibility of the materials employed on stages?"

This is not an easy question to answer; that the heating and lighting appliances, divided over manifold points of the stage, as well as manipulations with open lights, and even fireworks, are necessary for

modern theatrical performances, there is no doubt. In themselves they are not dangerous; but the danger lies in the great quantity of wood-work, gauze, coarse canvas, and other readily combustible materials of which scenery is made. If we remove the ready combustibility of these objects, not every spark or flickering gas flame will endanger the existence of the entire theatre, and the special danger of the stage and rigging-loft is immediately overcome.

The experiment of making certain pieces of decoration of an incombustible material has been tried many times, and with considerable success. Especially the flies, as being most exposed and hanging among the border-lights, have in some cases been made of fine wire gauze. The interstices were then filled with an incombustible substance, and the flies were then painted in the usual manner. This method certainly gives entire security against fire, and the greater amount of first cost is more than counterbalanced by their greater durability; but the inconvenience of handling such pieces is greatly increased by their greater weight, making them practically impossible for drops, and larger wings and flats.

Another device is to protect the wood and canvas by painting it with suitable materials, and thus to make it incombustible.

After the rebuilding of the "Opera House" at Munich (destroyed by fire, 1823) the wood-work was given a few coats of water-glass. This kept well for twenty years, but later trials showed that the coating of water-glass had changed its *chemical composition, and gave no further security*.

Water-glass is further objectionable on account of the gloss it imparts to scenery, thereby reflecting light, and spoiling the artistic effect of the painting.

The impregnation of scenery, before painting, has been strongly advocated, and especially of the aforementioned flies. Some of the different substances used for this purpose are alum, sodium sulphate, borax, the soluble fluorides, and calcium sulphate. It was claimed that by impregnation canvas became so far incombustible that it could neither propagate flames, nor glow for any length of time, and even under great heat would only char.

After the fire at the "Berlin Opera House" the authorities ordered the soaking of all scenery in a solution of alum.

The same question was raised, and given to a commission to decide, some twenty-five years ago, in Paris. On account of the report of this

commission an ordinance was issued enforcing the impregnation of all scenery. This was carried into effect in several theatres until, unexpectedly, some impregnated gauze was set on fire by the heat of a candle. The mayor had the case investigated. It was found that the ingredients used had lost their protective power, and had changed the chemical composition of the paint.

The writer ascribes the failure of these experiments to the manner in which the process was conducted; the canvas being, in all cases, merely soaked in the solution, and then dried and painted. If a piece of canvas is soaked in water-glass, and allowed to dry, the liquid, in losing its water, will contract more and more, until finally the solid particles will sit loosely on the *yarn* of the canvas.

Again, sodium tetra-silicate (water-glass being soluble in water) is dissolved on coming in contact with water. The water-colors used in scene painting may, therefore, have dissolved the greater part of the silicate at the start.

To obviate this the author would suggest the following: After thoroughly soaking the canvas in water-glass it should be placed in a dilute solution of hydrochloric acid; this would precipitate the silica inside of the *fibers* of the yarn itself. The reaction being the formation of silica, sodium chloride, and water; viz., $Na_2Si_4O_9 + HCl = 4SiO_2 + 2NaCl + H_2O$. The silica, being insoluble in water, could not be washed out, and, on account of its precipitation in the fibres, could not readily be thrown out, this process being a parallel case to the use of a mordant in dyeing; the linen in that case being first soaked in color, and this then precipitated (made fast) by the mordant. As silica has no gloss, this process would also get over that difficulty.

Of course, any other incombustible substance precipitated into the fibres will answer as well as the above.

Other solutions recently recommended for purposes of impregnation are: Versmann's and Oppenheim's, who advise a solution of 2 parts of sodium tungstate with 3 parts of sodium phosphate; Nicoll, one consisting of 6 parts of alum, 2 parts borax, and 1 part dextrine dissolved in soap-water; Siebdrath uses 5 parts of alum, 5 of ammonium phosphate, and 100 parts water; Patera, 15 parts borax, $11\frac{1}{4}$ parts of sodium sulphate, and 100 of water; Martin, 8 parts ammonium sulphate, $2\frac{1}{2}$ of sodium carbonate, 3 parts boracic acid, 2 of borax, 2 of starch, and 100 of water. And very recently it has been suggested to use a solution of magnesium chloride.

That something must be done to protect all easily inflammable parts, there is no doubt. The enormous danger of modern stages, and the dislike of insurance companies to writing these risks, will be a great factor in favor of the introduction of rational measures.

These remarks apply not only to stage-settings, but also to the light and flimsy suits of players, and especially to the dresses of the ballet. The great number of persons killed by the burning of clothing is astonishing. The sad death of the renowned dancer Emma Livery, Paris, 1862, and the burning to death of 12 persons at Philadelphia, February 17, 1861, are sufficient examples to show the necessity of this measure.

All the theatres of London have wet rags constantly on hand that, in case of accident, instant assistance may be rendered.

The combustibility of scenery is also greatly lessened by painting it on both sides, as the fuzz on the back of scenery, along which flames spread, is thereby destroyed.

The author's attention was first called to this fact by Mr. Higbee, chief machinist of the American Academy of Music, Philadelphia.

This gentleman held canvas painted on both sides within an inch of a "Bunsen burner," thus only charring it. The writer has frequently repeated this experiment, but he must here state that this only holds good as long as the canvas is well-covered with paint, and not after the paint has partly dropped off.

Scenery might be made much safer than it is by simply whitewashing the back of it, thus destroying the fuzz. This is an exceedingly cheap and simple operation, and there can be no excuse for not carrying it out.

Of late the use of asbestos for scenery, and especially for the "fire-drop curtain," has been agitated, but, as yet, nothing really practical has been done in this direction.

A fact not generally known is that it is not so much canvas scenery which is dangerous as the gauzes used in especially large quantities in spectacular pieces. This stuff is inflamed on the slightest provocation, and spreads like "wild-fire." It may be safely stated that a theatre which uses much gauze is *by far* more dangerous than one that uses little.

In its construction, a stage should be as nearly like the shaving-vault of a planing-mill as possible. The rear and two sides of the stage (including green-and dressing-rooms) should be enclosed by thick

brick walls, brick being the best masonry in case of fire. It stands when granite has disintegrated and marble has been burnt into lime.

The roof and roof-trussing should be made as nearly as possible fire-proof, as the rigging-loft is generally attached to the roof-trussing.

To divide the stage from the auditorium a wire drop-curtain becomes necessary. The failure of wire curtains in the case of the "Dresden Opera House," and again in the recent calamity at Vienna, has shaken public confidence in them. But in both cases negligence was the cause of their failure; the former was allowed to rust fast, and the latter was not let down.

It is necessary, therefore, that a wire curtain should (1), *be kept in perfect order;* and (2), *be automatic.*

It should be let down after every performance, and should not be raised until fifteen minutes before the beginning of performances. This would insure (1), its good order, and (2), would, in case of fire during the night, perhaps save the theatre.

A circumstance which has as yet not received the proper attention is the use of automatic curtains. At present the safety of theatres having wire drop-curtains depends entirely upon the coolness of the men having them in charge, and how little this can be depended upon the late Vienna fire clearly showed.

It is of the greatest importance that proscenium boxes should be of brick or iron, as some of the stage-settings are very near them, and in case of fire these boxes might be ignited in the time required by the curtain to lower itself.

The wall dividing the stage from the auditorium (proscenium wall) should be of brick; starting from the foundation, it should be broken by the *stage opening* and orchestra doors only. Above the *stage opening* an arch should be sprung, and the wall carried up on this at least 18 inches above the roof.

The joists and flooring-boards of the stage should not extend beyond one foot of the proscenium wall, as they would transmit flames to the wood work of the orchestra. In the same manner, the joists of the parquet should extend merely to this wall, and *by no means through it.*

The doors contained in this wall should be lined with iron, as solid iron doors, in great heat, soon become warped and useless, while iron-lined doors, in the greatest heat, retain their shape. This, at first sight, strange fact, is well known to "insurance men."

In case of fire a solid iron door offers no resistance to warping; in

a lined door, on the contrary, the sheet-iron, which tends to warp, is resisted by the interior wood, and when this burns into charcoal it still resists all warping tendencies. All doors contained in "fire-walls" should have springs or weights attached to them, so as to be at *all* times closed. Fire-doors can be shut automatically by a weight, which is released by the melting of a piece of very fusible solder employed for this purpose. "So sensitive is this solder that a fire-door has been made to shut by holding a lamp some distance beneath the soldered link and holding an open handkerchief between the lamp and link. Though the handkerchief was not charred, hot air enough had reached the metal to fuse the solder and allow the apparatus to start into operation."

These solders are alloys more fusible than the most fusible of their component metals. A few of them are: Wood's alloy, consisting of:

Cadmium,	1 to 2 parts.
Tin,	2 parts.
Lead,	4 parts.
Bismuth,	7 to 8 parts.

This alloy is fusible between 150° and 159° Fahr. The fusible metal of d'Arcet is composed of

Bismuth,	8 parts.
Lead,	5 parts.
Tin,	3 parts.

It melts at 173·3°. We can, therefore, by proper mixture, form a solder which will melt at any desirable temperature.

As before stated, one of the chief dangers of theatres consists in the numerous gas-flames, and not only of the stage proper, but also those of dressing-rooms. It seems impossible to supply actresses with enough light in dressing-rooms. A well-known prima donna, not being satisfied with large brackets on each side of her bureau, had twelve candles placed around her glass, as the informant remarked, "for her to see her ugly face." It is of the greatest importance that gas brackets should be supplied with wire baskets, and that swinging brackets should be allowed under no circumstances; and still proprietors of theatres have constant annoyance by actors tearing off these wire covers.

That not only the gas brackets of dressing-rooms, but *all* brackets, should be protected by wire baskets, and that all swinging brackets should be eschewed, goes without saying.

Particular attention should be paid that foot and border lights are covered with wire screens. These lights should be lighted by electricity, as many fires are caused by retaining the old method of lighting, by alcohol lamps suspended on long poles. A careless or intoxicated man tries to light the border lights, strikes, with his lamp, a piece of gauze, and in a short time the whole building is in flames. Considering the proximity of these lights to flies, it is wonderful that this is not a more frequent occurrence than it is. Care should be taken to keep flies, and especially those of gauze, at a proper distance from border lights. Many fires have been caused by allowing scenery to hang over these lights.

We must now briefly turn our attention to fire appliances in theatres. Every great disaster causes a temporary fit of virtue among theatre managers, during which new fire appliances are introduced; but very soon this dies away, and appliances are allowed to become out of order and worthless.

The simplest and one of the best of fire appliances is the "fire-bucket." A bucket of water at hand to be thrown on a flaming piece of gauze is worth all the fire appliances in the city fifteen minutes later. Therefore, fire-buckets should be kept *constantly filled* all over the premises, for an empty bucket is worse than none, as it only takes up space. These should be kept not only on the floor of the stage, but also in its most dangerous part, the rigging-loft.

Plugs with hose attachment should be placed in every part of the building—the galleries of the auditorium, the stage, the rigging-loft, etc., etc., as there cannot be too many of them. The closets containing them should be marked with large letters, as FIRE PLUG. Frequently firemen, on arriving at burning theatres, have no idea where the plugs were, as they are all boxed up. A skillful designer can readily make these tasteful in appearance.

All plugs should have their hose attached, ready for instant use, as no one would take the nozzle off of a plug and attach the hose in the midst of the smoke and flames of a burning stage.

(To be continued.)

Report of the SPECIAL COMMITTEE on the POLLUTION of the SCHUYLKILL RIVER.

The committee to whom was referred the question of the pollution of the Schuylkill by sewage matter respectfully report:

That they have carefully examined the subject and find that among a number of very bad sewers that empty into the Schuylkill river, in or near the city limits, none, in their opinion, requires such immediate attention as that entering the river near the eastern end of the Girard avenue bridge.

The circumstances that render this sewer especially dangerous to the public health are:

1. The position of its outlet; and
2. The character of its drainage area.

As regards the first circumstance, the sewer in question empties into the river within a few feet of the inlet of the Spring Garden water works, and within about a mile of the Fairmount forebay.

As regards the second circumstance, the sewer drains a large district that is rapidly increasing in density of population, and receives the drainage of large breweries, slaughter yards, manufactories, and the kitchen slops and water-closet filth of a comparatively large population.

Although the inlet of the Spring Garden water works is further up stream than the mouth of the sewer, yet it is so near it that some of the sewage must pass directly into the pumping reservoir.

It can do this, among a number of ways,

1. By extended eddying movements in the river water;
2. By currents occasioned by strong winds; and
3. By currents due to the passage of steamboats.

The result of the contamination of the Spring Garden basin, so effected, cannot fail to greatly increase the mortality of the districts deriving their water supply therefrom.

The Fairmount water works, though much further from the sewer's outlet, are, however, situated down stream, and therefore in a position to receive the direct discharge. Lying, as they do, too near the outlet to be sensibly purified by exposure to air, sunshine and settling, and being on the same side of the river, and in nearly the direct line of

the current carrying the sewage matter, they cannot fail to be contaminated to an extent highly dangerous to the public health.

The water discharged by the sewer in question is disgustingly foul. It is not a rare thing to find floating in it fecal matter and shreds of putrefying animal substances derived from slaughter-houses draining into it. Were ocular demonstration absent, the foul odor, which may be detected at a considerable distance from the sewer's mouth, speaks forcibly of the dangerous character of this discharge.

The larger particles, carried in suspension in the sewage water, settle soon after entering the river, and form a bank or shoal highly contaminated with sewage. This bank is forming along the eastern side of the river near the sewer's mouth. Lying, as it does, in the direct path of so much of the water that enters the Fairmount basin, it forms an objectionable feature that should be removed as soon as possible. The bubbles of gas that can be seen escaping from this bank, especially during warm weather, arise from the slow decomposition of the organic matter it contains.

The filthy water discharged from the mouth of the sewer does not immediately mix with the river water, for being warmer and lighter, it floats for a while on the surface, just as a film of oil does on water. It is the entrance of this comparatively unmixed sewage into the forebay of the Spring Garden works, by the means already pointed out, that causes the most serious contamination of its waters.

Even when the water reaches the forebay of the Fairmount works, the sewage is mixed with but a comparatively small proportion of the entire discharge of the river. The contamination, however, from this cause varies with the conditions of the river; when the water is not flowing over the Fairmount dam, the forebay, disregarding the water passing through the canal locks, receives an average of the entire river discharge, thus tending to lessen the degree of contamination. When, however, as is the case during most of the year, the water is flowing over the Fairmount dam, the water entering the forebay comes chiefly from that flowing along the eastern bank of the river, which is the part mainly contaminated by the sewer in question.

The most objectionable matter emptied into the river by this sewer is, without question, the water-closet discharges. Such matters, even when thrown off from healthy persons, cannot fail to be highly contaminating to the water. But when thrown off from diseased bodies, especially from such diseases as typhoid fevers and other zymotic diseases,

form sources of the gravest danger; quantities too small to permit of chemical analysis having in many instances been shown to be quite sufficient for the spreading of disease.

Next in the order of their dangerous character are, perhaps, the discharges from slaughter yards. The danger arises not only from the nature of the discharges themselves, but also from the rapidity with which putrefactive changes occur therein.

In considering the character of the water supply of the city, your committee would respectfully call attention to the desirability of having frequent chemical analyses made of the water as it is actually delivered in different sections of the city, so as to call instant attention to any marked changes in the amount of organic matter therein, and yet, at the same time, they would plainly express their opinion that chemical analysis alone cannot be depended upon as an infallible test, since, as already mentioned, the presence of infectious matter in water, in such quantities as either to escape chemical detection altogether, or to produce but an insignificent increase in the total quantity of organic matter, may render the water highly objectionable to the health of districts supplied by it. *An absolute exclusion of all water-closet drainage* into the river at any portion of its course above the city would, therefore, appear to be absolutely necessary in order to maintain unquestioned purity.

As a temporary means for remedying the evil of the sewer in question, your committee would respectfully suggest to the proper city authorities the possibility of connecting the present inlet of the Spring Garden water works through a suitably constructed channel extending to some point near the middle of the stream, where the contamination is less marked.

As a relief for the Fairmount forebay, your committee are unable to see how the evil can be remedied except by the construction of an intercepting sewer built along the eastern side of the river, and discharging the sewer in question far enough below the Chestnut street bridge as to avoid all nuisance to the southern section of the city. Such a sewer might be made a part of a general system of sewerage protecting the entire river bank as far north as Manayunk or even beyond.

In suggesting remedial measures for maintaining the purity of the water supply of the city, your committee would respectfully ask that the proper authorities carefully consider whether the purity of the

rivers that now supply our city can be readily maintained for a very long time to come, without the enactment of restrictive legislation that must seriously cripple our industries.

The constantly increasing population of the valleys of the Schuylkill and the Delaware, the natural tendency of manufactories to seek the cheap water transportation, together with the fact that the river channels offer the only natural drainage of the cities and towns situated in their basins, must, in the near future, lead to such a contamination of the water as to render it unfit for drinking purposes.

When a river becomes too contaminated to longer offer a safe source for drinking purposes, there are but one of two courses to pursue, viz.: either to seek some higher source, beyond the possibility of sewage contamination, or to endeavor to permit the water to purify itself by the construction of sewers that shall receive the sewage and discharge it below the source of supply.

It is a matter of grave doubt whether the second method can, in the case of our water supply, continue for any considerable time to be a protective one. As the objectionable drainage is poured into the rivers at greater and greater distances above the city, it will become more and more difficult and expensive to construct sewers to carry it past our pumping stations.

It would, therefore, in the judgment of your committee, seem advisable on the part of our city authorities, before expending any considerable sum, to carefully consider whether it is not truer economy to do now, what will in all probability have to be done in the near future; viz., to seek another source for our water supply.

Where shall we look for this source? In view of the importance of this inquiry, your committee do not feel prepared, without more study than they have been able to give the matter, to recommend any particular source as suitable for the required supply. They would, therefore, recommend to the proper city authorities a thorough inquiry into the availability of the Perkiomen, and other sources that have been recommended for the purpose.

If, however, any new source is to be utilized for the supply of the city, it will not only be advisable but necessary that steps be at once taken to protect the entire area draining into such source from the effects of all contamination.

Although your committee fully appreciate the importance of considering the possibility of obtaining a purer water supply for the city,

yet they are fully aware of the advantages that would arise to the general health of the city from the construction of an intercepting sewer along the eastern banks of the Schuylkill from Manayunk or beyond, and with an outlet sufficiently below the densely populated portions of the city as not to be objectionable.

EDWIN J. HOUSTON,
FRED. GRAFF,
REUBEN HAINES.

RECENT IMPROVEMENTS IN THE MECHANIC ARTS.

ELECTRIC FLAT-IRON.—This novel flat-iron is chambered out near its smoothing face, forming a cavity for the reception of an electrical resistance, the latter being connected by suitable wires with a galvanic battery. The face of the flat-iron is heated by the radiation from the electrical resistance. A layer of non-heat-conducting material is placed above the cavity in the iron to confine the heat to the face of the iron.

NOVEL POCKET CAMERA. A late important invention, which is designed especially for field use, consists of a tripod-head and double plate-holder adapted to be used with what is known as the Walker apparatus. The tripod-head is adapted to be detached from the camera and folded up in a very small compass. The double plate-holder, being made of hard rubber, is jointless, and consequently unaffected by moisture. It is by reason of this important invention that it is possible to reduce the dimensions of the camera to pocket size, and also by means of commercially prepared gelatine dry plates to take instantaneous views. This camera, tucked conveniently in the pocket, (or carried like a field-glass in a leather case), with the legs of the same packed in the compass of an umbrella, is a fishing-tackle with which the canoeist can catch anything, from clouds and mountains, down to a glimpse of a little lake with a string of speckled trout hung in the foreground. I believe no apparatus has ever been manufactured hitherto having such regard for perfection of detail as that made by the Walker Company, of Rochester, N. Y.

A NOVEL STEAM-ENGINE.—This important improvement in steam-engines appears even to many experienced engineers a sort of mechanical paradox. With but one crank; with two cylinders cast in one piece; and only one valve chest, the entire engine is as simple and few in parts as the simplest of ordinary single cylinder engines. It has no dead centres, but will start forward from any possible position in which

it may be placed. Further, it may be stopped, started, and changed from a single to either a double or compound engine, as may be desired, by the motion of a single lever, and the change to either form may be made while it is moving at any speed, just as easily, it is asserted, as when it is still. The engineer can run it with one cylinder as a single engine, or with both cylinders, using live steam, as a double engine, or with one cylinder, using live steam, and the other running by the expansion as a compound engine, either way as economically as any engine especially built for that particular way.

FIRE-PROOF CURTAIN FOR THEATRES.—A recent German invention has been gotten up by Herr von Falkenhausen for separating the stage from the auditorium in theatres in the event of breaking out of a fire. The curtain, which is closed at the sides and open at the bottom, is secured at the upper end to a perforated water-pipe. The other end is rolled up on a roller stationed above and in front of the water-pipe, so that when the water is turned on the weight of the wet curtain nearest to the water-pipe will tend to unroll the curtain until it falls down.

ATTACHMENT FOR TELEPHONES.—This invention has for its object the closing of the unused ear when using the telephone receiver and mouth-piece. The attachment consists of a bent spring having means at one end adapting it to be secured to a telephone tube, and bearing at the other end a pad which, when the attachment is in position, closes the unused ear. A set-screw is used in connection with the device by which the bent spring (which passes around the head of the operator) is secured to the telephone, and serves to modulate the pad pressure.

A NEW CALENDAR.—This calendar consists of a frame of card-board, doubled in long folio and provided with perforations and notched edges. Dials are used containing the days of the week and the days of the month pivoted within the frame, and adapted to register with the openings formed therein. A tear-off tablet is attached to the face of the frame. Two dials are used, one of which is smaller than the other, and carries three figures and a blank, while the larger dial carries ten figures, the dials being arranged so that the smaller one shall partially overlap the other, and while exposing its own figure at its own aperture shall conceal the figure on the larger dial which would otherwise be exposed at the aperature of the small dial, another figure of the larger dial being exposed at a second aperture.

F. B. BROCK.

Washington, D. C.

Photographs upon Faience.—M. De Luyener has presented a report to the Société d'Encouragement upon the experiments in photographing on hard faience by M. Cacault, at Colombes. The photographs were taken upon the fine hard faience of Creil; they are baked upon enamel at a single heat, in a temperature about equivalent to that of boiling varnish.—*Chron. Industr.*, No. 21, p. 209. C.

Meteorological Apparatus on the Puy de Dome.—In October, 1881, a work was begun on the summit of the Puy de Dome, which may serve as a model for other mountain observatories. A circular terrace, bordered by a balustrade 1 metre (3·2800 feet) high and 30 inches in circumference, has been arranged around the tower of the summit for meteorological service. The balustrade is divided into 360 degrees, and the degrees are engraved in the cap stones. North is at 0°, east at 90°, south at 180°, and west at 270°. More than 300 localities have already been referred to this graduation. The chief peaks of Mts. Doré, Cantal, Forey, and all the volcanic region of the Domes are found in a few minutes. By means of telescopes, which can be brought to any point by two cars rolling upon rails, all the curious details of this immense landscape, embracing seven departments, may be easily seen. On the north there is a group of about 40 volcanoes, stretching over a length of four leagues, and at distances of from two to three kilometres (1·2403 to 1·864 miles) from one another, embracing an arc of 60°. At the south there is a like volcanic group, but more crowded and comprised in an arc of 40°. At a greater distance, towards the S. S.W., is the mass of Mt. Doré between 195° and 220°; still further off are a portion of the Cantal Mountains between 190° and 194°. The Forey Mountains border the horizon from N. E. to S. E., between 60° and 120°; at 87° there is an opening, through which may be seen, at a very great distance, three very lofty peaks, which appear to belong to the same mountain. The chart of France and a simple calculation show that this is Mont Blanc, at a distance of 280 kilometres (174 miles). Maps have been constructed with concentric circles at distances of four kilometres (2·4855 miles), having the observatory for a centre and indicating the approximate distance of all the points observed. The advantages of this arrangement for tracing the origin and progress of storms, the heights of clouds, the places where they are most often formed, the place and altitude of fogs or mist, and other meteorological phenomena, are obvious.—*Comptes Rendus,* xciv, 1095. C.

Production of Organic Compounds by Electrolysis.—The experiments of Bartoli and Papasogli have been extended to the electrolysis of a lye of soda or potash by the aid of four to six large Bunsen cells, yielding hydromellate and probably also pyromellate. Upon the positive electrode little gas is disengaged, but there is a large accumulation upon the negative. The weight of the carbon diminishes but little. In mineral acids, such as sulphuric, nitric and hydrochloric, six cells are sufficient to transfer some kilogrammes of carbon to the positive pole. After filtration the liquid does not turn brown; the deposited carbon is a black substance with a conchoidal fracture, and presenting, upon its broken surface, a brilliant substance which is not produced in the alkaline liquids, and which, in oxygen, is converted, at the ordinary temperature, into mellitic acid and its derivatives. This substance dissolves slightly in water—better in warm water, and is precipitated by acids and mineral salts. It is also soluble in alkalies and concentrated sulphuric acid, from which it is precipitated by water. This substance is called mellogene or mellitogene. It is also produced in the decomposition of formic, acetic and oxalic acids.—*La Lumière Electrique*, vi, 357. C.

Great Magnetic Disturbance.—Important magnetic disturbances were observed in France between the 6th and 20th of April. On several days the telegraphic lines in nearly all directions were traversed by accidental currents; at certain hours the interruption was so great that despatches could only be sent on closed circuits with but a single earth contact. The international lines gave the same results; it is therefore probable that there was a magnetic storm of great extent, of which the effects were felt in the whole northern hemisphere. Phenomena of this kind are of great importance in the study of terrestrial magnetism. Mascart has recorded the principal phases as they were observed at the College de France, and has given a description of his apparatus. The storm did not break out suddenly; it was heralded for several days by an almost constant agitation of the magnetic needle. The first great shock began at 11h. 45m. P. M. on April 16, and affected simultaneously the three elements of declination, inclination, and intensity. Another similar shock occurred on the 20th. During the whole time the register of atmospheric electricity did not show any disturbance which seemed to be connected with the magnetic phenomena.—*Comptes Rendus*, xciv, 1173. C.

Differences of Sea Level.—During a voyage to and from Campbell Island, M. Bonquet de la Grye made a series of observations upon the saltness and density of the sea-water. Many meteorologists have thought that there should be an intimate relation between the saltness of the ocean and the currents which traverse it, but processes of exact investigation have been hitherto employed only in laboratories and upon a limited number of samples. Mohr's process for the investigation of chlorides, which has been popularized by M. Roux, is not only exact, but in can be employed upon shipboard under all circumstances. It requires neither accurate weighings nor difficult precautions: the moment is marked at which a change of tint is made by the addition of bichromate of potash, and a simple reading upon a graduated tube, or counting the drops of the experimental liquid, is sufficient to give, with great accuracy, the weight of the chloride which is contained in a given quantity of water. By means of this process de la Grye has constructed a chart of the relative levels of the Atlantic Ocean between 15° and 45° north latitude.—*Ann. de Chim. et de Phys.*, April, 1882. C.

Attraction of Metals at a Distance.—M. Pellat has lately observed that the surface of a metal undergoes an alteration in its nature, by the neighborhood of another metal, at ordinary temperatures. This alteration has been shown by measuring the difference of potential, between the surfaces of the two metals. If one of them is placed in the neighborhood of a third influencing metal, while the other is removed from that influence, it is immediately found after withdrawing the influencing metal that the difference of potential between the two primitive surfaces has changed. This modification requires some minutes to become sensible, and increases with the duration of the influence, until it reaches a definite limit. When the influence ceases the modification diminishes rapidly at first and then slowly. The amount of variation depends upon the influencing metal. The most striking effects have been obtained with lead and iron; copper, gold, and platinum produce effects which are slightly less; zinc produces no change. M. Pellat attributes this modification to a volatile body or vapors emanating from the influencing metal, which would be deposited upon the influenced metal, and would thus change the nature of its surface.—*Les Mondes*, May 13, 1882. C.

Decoration of Glass Without Heat.—Ernest Dumas has presented a favorable report upon the decoration of glass by the method of M. Lutz-Knechtle, of Frogen, Switzerland. He adds zinc white, or ultramarine, to a solution of silicate of soda or of potash, so as to produce colors which can be applied to the glass in various ways. These colors dry very quickly and will bear hard washing. *Chron. Industr.*, No. 21, p. 259. C.

New Pump for Compressing Gas.—M. Cailletet has invented a pump for compressing and liquifying gases, such as protoxide of nitrogen or carbonic acid. The copper piston of the old forms of apparatus has been replaced by a steel plunger, lubricated with mercury. This pump, which a single man can operate, compresses at each revolution of the fly-wheel a third of a litre (·352 quart) of gas. In an hour four or five hundred grams (·8 to 1·01 lb.) of the liquified carbonic acid or protoxide can be easily obtained —*Chron. Industr.*, No. 21, p. 259. C.

Origin of Atmospheric Electricity.—Van der Mensbrugghe recalls the experiment, which was made in 1816 by Dessaignes, of plunging a rod of glass into mercury. The electricity which is shown was attributed by the experimenter to the friction of the glass against the surface of the mercury, but Spring found that if the surface of mercury is covered with lycopodium, so as to diminish the friction, the electricity remains the same. It has, however, been found to vary with the temperature and with the degree of oxidation of the mercurial surface. Mensbrugghe demonstrated, five years ago, that every liquid mass, of which the surface is expanding or contracting, becomes the seat of a thermo-electric current; if the variation of surface is produced near a bad conductor, such as glass or air, the current excites phenomena of static electricity. This hypothesis greatly facilitates the explanation of atmospheric electricity, provided that the spherules which constitutes mist and clouds are constantly undergoing great variations of surface. Many of the luminous phenomena which accompany the shower of mercury, when forced through a porous cup by atmospheric pressure, or when shaken in a glass vessel in a darkened room, confirm these views, and they may be regarded as a natural introduction to the study of the development of atmospheric electricity, a question of great interest to investigators in all countries.—*Bull. de l'Acad. de Belge.* C.

Hydraulic Riveting.—The advantages of hydraulic riveting are described as follows in the journal named below: "Under the enormous pressure of the hydraulic riveter the iron of the rivet is crowded back over its whole length, and welds to fill the void exactly, whatever may be its shape, so as closely to unite the plates, even when they are numerous and of considerable thickness. The grip is so strong that all the seams disappear, and after the riveting is done the plates, course-irons and rivets seem to form but a single piece. The rivets of the mounting-bolts can be removed by hand." Messrs. Greig and Eith, in 1879, reported the following comparative resistances: hand-riveting ·405, steam-riveting ·509, hydraulic-riveting ·559. These figures are evidently in favor of the hydraulic riveting.—*Le Genie Civil*, ii, 289. C.

Book Notices.

THE PRACTICE OF COMMERCIAL ORGANIC ANALYSIS. By Alfred H. Allen, F.I.C., F.C.S. Vol. II. Philadelphia: Presley Blakiston & Co., 1882.

This is a valuable work,—the more valuable as it is the only treatise of the kind in the English language. There are, indeed, several manuals of organic chemistry to be found upon scientific shelves, but as most of them attempt to cover the entire field of the carbon compounds—including a host of derivatives of theoretical value only—they may be said to have more of the feature of a glossary than of a practical and exhaustive treatise.

In the volume before us the author discusses only five groups of bodies: the hydrocarbons, fixed oils and fats, sugars, starch, alkaloids and organic bases. Under these heads are included such a number and variety of substances that any satisfactory description of them is impossible here.

The various hydrocarbons, petroleum, burning oils, lubricating oils, benzine, anthracene, etc., are exhaustively treated in the first division. Animal and vegetable oils, fats, fatty acids, soaps, etc., are next in sequence. The third chapter comprises a thorough description of polariscopes and the testing of sugars, both by optical and chemical means, and closes with a subject now attracting much attention, viz: glucose. The examination for sugar in the disease known as *diabetes*

mellitus is also described. Cellulose, the various vegetable fibres, gun-cotton, starch, gums, are comprised in the next chapter, which closes with a clear and exhaustive description—with tables—of the proximate analysis of plants.

The final one hundred and fifty pages of the volume are devoted to the alkaloids, cinchona barks, quinine, opium, strychnine, toxicological analyses, nicotine, tobacco analysis, and closes with a long account of the various aniline colors.

The above gives an idea of the scope of the work. The great bulk of the subject matter, of course, is, as the title indicates, devoted to the methods of analyses. There are many tables of specific gravity, solubility, melting and boiling points, etc. The manufacture of most of the bodies is described. Practical tests, factory assays, and trade customs are frequently noticed. The book is practical and exhaustive in each of the subjects described. The author, who stands at the head of his profession in England, writes with that thoroughness and authority that comes only from a personal familiarity with the questions he discusses.

The work will be found valuable, not only to the analyst, but also to the manufacturer, and to any one who desires in this branch of science an excellent book of reference. H. P., Jr.

Steam Economy, as Illustrated by the Use of the Steam Engine Indicator, Practically Considered; Being a Reflex of Actual Tests. By G. A. Wilkinson, M.E. Published by the Author: Philadelphia, 1882.

This work is intended for steam-users, drawing their attention to the importance of economy in the generation of steam in boilers, and its use in the steam engine; and in those parts of the book which are from his own pen the author dwells mostly on the advantage of having proper tests made of boilers and engines, using the indicator, etc., and entrusting such important duties to competent experts only, giving from his own experience cases (illustrated by indicator diagrams), where considerable economy was attained after proper changes (sometimes very trifling) had been made.

There is no doubt that a great deal of guess work is still indulged in by steam users and their employés, and that many engine builders, partly from ignorance, partly from self-interest, are indifferent in the matter, as long as they can only sell their engines.

But to steam users economy is the great question, and the expense of a proper and careful test is insignificant compared with the continuous saving afterwards.

Articles collected from different sources on the "care of boilers," "some points in engine building," "belting," "setting pumps," "piston-rod packing," etc., contain useful information. Tables on the properties of steam, strength of materials, mean pressures at different rates of expansion, etc., are given. In the last-mentioned table, however, no account seems to be taken of clearance, release and condensation.

J. H.

THE WATCH AND CLOCKMAKERS' HANDBOOK. By F. J. Britten. Fourth Edition. London: W. Kent & Co., Paternoster Row, and Grimshaw and Baxter, 35 Goswell Road. 1881.

The purpose of the author of this little volume is not to offer to the watch and clockmakers a scientific treatise on horology (he does not even claim the matter he offers in his book to be well arranged), but it is intended mainly to present in plain and concise language the collected experience of practical men, this being especially needed by those watch and clockmakers engaged in the repairing of timepieces, and this claim is certainly well sustained. That part of the book devoted to astronomical phenomena, more particularly the division of time and its cycles, is admirably well presented, and intelligible to any average mind, though quite unpracticed therein. The same is true of the more elementary portion devoted to the construction of time-pieces. The more essential details of the mechanism of watches and clocks, such as main-springs, hair-springs, balances, pendulums and escapements, are dwelt upon with the greatest of care and most judicious attention. Whoever consults the methods given in this book of examining the various watch and clock escapements, to recognize their advantages or disadvantages, or to discover faults and how to remedy them, will have herein a good and reliable guide.

The necessary tools and their modes of usage are well described, and an appendix under the name of "Useful memoranda" is added, giving many old and new modes of performing work of various descriptions, such as almost every one will meet with, more or less frequently, if engaged in the repairing of time-pieces.

It would be a decided improvement to the book if all its illustrations were lettered, so as to make reference easier. L. H. S.

THE KINEMATICS OF MACHINERY. Two Lectures relating to Reuleaux's methods. Delivered at South Kensington Museum. By Prof. Alex. B. W. Kennedy, C. E. With an introduction by Prof. R. H. Thurston, A.M., C.E. New York: D. Van Nostrand. 1881.

The study of Reuleaux' Kinematics of Machinery requires more than cursory reading of his voluminous work, and many engineers and students intending to master the subject are apt to be discouraged on seeing, after a first glance through the volume, the amount of work and careful study before them.

The two lectures printed in the above-named publication form a concise, but very clear treatise on this method, avoiding all terms which are not familiar to every mechanical engineer, and enabling those whose limited time will deter them from a study of the complete work to obtain a very fair knowledge on the subject in question. Even those who purpose studying Reuleaux' work will do well to prepare themselves by a preliminary perusal of the above publication, as they will see their way much clearer through the intricacies of the larger volume.

The publication can well be recommended to every mechanical engineer. H. B.

Franklin Institute.

HALL OF THE INSTITUTE, June 21, 1882.

The stated meeting of the Institute was held this evening at the usual hour, with Vice-President J. E. Mitchell in the chair.

There were present 68 members and 7 visitors.

The minutes of the last stated meeting, and of the special meeting, held May 21, were read and approved.

The Actuary submitted the minutes of the Board of Managers, and reported that at the stated meeting, held Wednesday, June 14, 15 persons had been elected members of the Institute. He also reported, under instructions, a letter of Mr. A. E. Outerbridge, Jr., relating to a donation to the Building Fund, and a resolution of thanks from the Board to the donor.

Mr. Thomas Shaw, from the Special Committee on Patents, made a brief verbal report of the results of the committee's visit to Washing-

ton, and of what the committee had learned of the state of affairs respecting the proposed amendment to the patent laws. Remarks were also made by Prof. E. J. Houston and G. Morgan Eldridge, the other members of the committee. The committee, through its chairman, proposed to present a written report for the next meeting of the Institute.

Prof. Houston, chairman of the Special Committee on the Pollution of the Water of the Schuylkill, presented and read a full report on the subject. It described in detail the pollution of the drinking water due to the sewer emptying into the Schuylkill at Girard avenue bridge. The committee reported that they deemed it advisable to recommend the city authorities to seek a new water supply free from the dangers of contamination. Steps should then be taken to protect such a source of supply from any possibility of future contamination. The committee also reported in favor of an intercepting sewer along the eastern bank of the Schuylkill, from Manayunk or beyond, and with an outlet sufficiently below the densely populated portion of the city not to be objectionable. The report was signed by Edwin J. Houston, Fred. Graff, and Reuben Haines. The report appears in the JOURNAL for August.

On motion the report was adopted with the thanks of the Institute. It was also decided that an official copy of the report be sent to the City Councils, as the sense of the Institute on the subject.

Mr. Shaw said that he knew something from observation, both of the pollution of the Schuylkill and the purity and value of the Perkiomen water. He expressed the opinion that Philadelphia could, by using the latter source of supply, get clear and pure spring water delivered to consumers at less cost than that of the present muddy and impure supply.

Mr. Robert Grimshaw then read the first paper of the evening, "On the Use of the Microscope in Engineering." The speaker showed that the microscope might render important service to the engineer, in enabling him to determine the quality of materials of construction. The paper was illustrated by the exhibition of photographs, showing good and poor bridge timbers, etc. An abstract has been prepared for publication.

A paper on "Tests of Raw Hide Belting," by Mr. John E. Hilleary, in the absence of the author, was read by the Secretary. The paper has been referred for publication.

Charles J. Hexamer then read a paper "On the Prevention of Fires in Theatres." The speaker dwelt upon the great loss of life that frequently attended the burning of such buildings; he dwelt upon some of the principal defects in the construction and arrangement of theatres, and upon the remedies that had been suggested to meet them, and advanced some suggestions of his own.

The paper was discussed by Messrs. Graff, Cooper, Grimshaw, and the author, and has been referred for publication.

It was decided to appoint a committee to investigate the subject of the "Prevention of Fires in Theatres," and the chairman named the following members to serve on the committee, viz.: Thomas Shaw, Charles J. Hexamer, Henry R. Heyl, J. E. Mitchell, and Robert Grimshaw.

Mr. Wm. B. Cooper then followed with a statement of some additional facts relating to the subject of his previous papers.

The Secretary's report which followed, and which was abbreviated on account of the lateness of the hour, embraced a description of Henry B. Riehlé's wedge clamp for holding flat bars in a testing machine; Knox and Shain's trepezoid odontograph for laying out interchangeable gear teeth; H. Wocher's patent window fixtures, allowing the removal of the sash for cleaning; Potter's belt hook, exhibited by the Novelty Belt Hook Company; the excelsior testing seive, with many changes of bolting cloth; the Day spacing or shading square for mechanical draughting, and Huffnagle's sub-marine lantern, with air tubes for carrying oxygen to and from the otherwise hermetically-closed lamp.

On motion of Mr. Burk, it was resolved that the Committee on Meetings be requested to consider during the summer vacation, and report in September, some means of providing more time for the consideration of new inventions and of the Secretary's report on Progress in Science and the Arts.

Mr. Mitchell invited Mr. G. M. Eldridge to the Chair and gave a brief history of the John Scott Legacy, left to the City of Philadelphia in 1816, the interest on which is to be laid out in premiums to be distributed "among ingenious men and women who make useful inventions," in sums not to exceed \$20 to each, and with a copper medal to be inscribed, "To the Most Deserving." He stated that the fund now amounted to \$34,000, and that the Committee on Minor Trusts, of the Board of City Trusts, had adopted a resolution, which was read by

the secretary, declaring that they would favorably consider any recommendations made by the Franklin Institute for the award of this legacy. He offered the following preamble and resolution, which after some discussion, were adopted.

WHEREAS, The Directors of City Trusts have directed the chairman of Committee on Minor Trusts to inform the Franklin Institute "that they will favorably receive the names of any persons that the Franklin Institute may from time to time report to the Committee on Minor Trusts as worthy of receiving the Scott Medal and Premium."

Resolved, That the above offer is hereby accepted.

After considerable discussion as to the manner in which the recommendations of the Scott Legacy Medal and Premium should be made, participated in by Messrs. Orr, Sartain, Mitchell, Weaver, Shaw and Grimshaw, it was finally decided, on motion of Mr. Mitchell, that the recommendation of the award be entrusted to the Committee of Science and the Arts.

Mr. Heyl, chairman of the Committee on Science and the Arts, called for the reading of the following communication, viz.:

Philadelphia, May 17, 1882.

The Committee on Science and the Arts of the Franklin Institute have recently prepared a form of Certificate of Merit to be presented as an award to applicants before the Institute, whose inventions or productions have been reported upon by your committee as worthy of such commendation.

This certificate is intended to be of such size and design as will render it a suitable one for framing, and yet not be an expensive one.

Your committee have prepared in advance such a form of certificate, and beg to be permitted to present it herewith, asking the Institute to sanction it, and empowering the Committee on Science and the Arts to award and issue the same.

Respectfully submitted,

H. R. HEYL,

Chairman of Committee on Science and the Arts.

To the Franklin Institute of the
State of Pennsylvania, Philadelphia.

After the reading Mr. Heyl explained in full the object and wishes of the committee in preferring the request, and offered the following resolutions which were after some discussion adopted, viz.:

"*Resolved*, That the Committee on Science and the Arts of the Franklin Institute is hereby authorized to award and issue to persons by said Committee adjudged worthy, a certificate of Merit for their inventions, discoveries or productions, which certificate shall read as follows:

The Franklin Institute of the State of Pennsylvania, for the Promotion of the Mechanic Arts, Awards to this Certificate of Merit.

This award is made pursuant to the recommendation of the Committee on Science and the Arts.

Report No. , Approved , 18

Chairman of Committee on Science and the Arts.

President.

Secretary.

"*Resolved*, That all such Certificates of Merit so awarded shall be signed by the President and Secretary of the Franklin Institute, and the Chairman of the Committee on Science and the Arts, and attested by the seal of the Institute, and be transmitted to the person named therein by the Secretary."

On motion the meeting was adjourned.

WILLIAM H. WAHL, *Secretary.*

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JOURNAL

OF THE

FRANKLIN INSTITUTE.

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXIV. SEPTEMBER, 1882. No. 3.

ON A NEWLY DISCOVERED ABSOLUTE LIMIT TO ECONOMICAL EXPANSION IN THE STEAM ENGINE AND IN OTHER HEAT-MOTORS.

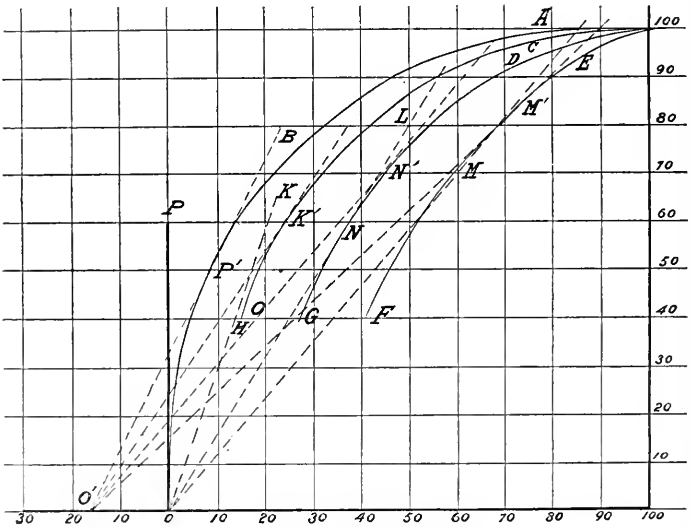
BY ROBERT H. THURSTON, FELLOW OF THE A.A.A.S.

[Read before the American Association for Advancement of Science, Montreal Meeting, August, 1882.]

It has been universally assumed by engineers, and probably by all physicists familiar with the theory of the steam engine hitherto accepted, that the best ratio of expansion, whether for maximum efficiency of fluid, of engine, of capital, or of plant,* increases with increase of steam pressure without limit, and that such ratio may be indefinitely increased with decrease of the ratio of back-pressure to initial pressure for any one kind of engine, notwithstanding the fact that the value of the ratio of expansion is modified by variation of the conditions of working, even where the ratio $\frac{p_b}{b_1}$ is the same. The writer now proposes to show that, in every actual engine, in every engine operated

* *Vide* a paper "On the Several Efficiencies of the Steam Engine," etc., JOURNAL OF THE FRANKLIN INSTITUTE, May and June, 1882; *Transactions of the American Society of Mechanical Engineers*, 1882.

under the conditions of real work and of usual practice, there exists a limiting value of any of these "ratios of maximum efficiency" beyond which it cannot be economically raised even with an infinitely elevated boiler-pressure. It will be further shown that this "absolute limit" may be readily, and probably often is, passed in every-day practice, that in the usual forms of steam engine an absolute limit exists within or not far beyond the customary working range of expansion, beyond which expansion cannot be carried with economy however high steam pressure may be adopted; in other words, with infinite pressure, the economical value of the ratio of expansion will be found often not merely finite, but sometimes probably within the limits of familiar practice.



CURVES OF EFFICIENCY

In earlier papers* the writer has shown that the conditions under which engines are worked in actual practice differ in a very important degree from those assumed in the simple thermo-dynamic theory of heat engines, and, especially, that the unjacketed steam cylinder, which is usually assumed to be of non-conducting material, is to such a serious extent a reservoir and a transferrer of waste heat that the efficiency of the engine is greatly and sometimes enormously reduced.

* JOURNAL OF THE FRANKLIN INSTITUTE, May, 1881, February, May, and June 1882; *Transactions of the American Society of Mechanical Engineers*, 1881–2.

The equations which would give values of the ratios of maximum efficiency for the ideal "perfect engine," therefore, do not apply to real engines, and the author has deduced* modified equations, which are at least approximately correct for real practice. He has also produced true "curves of efficiency" from real engines, which were found to be practically the same in form and location, to be practically identical in character with those inductively obtained, so far as the two could be compared.

These curves have the equation

$$\frac{y}{x} = b^2\, r^{2q} \frac{n - r^{1-n}}{n - 1}$$

in which b is a constant factor; r is the ratio of expansion and a function of x; q is an exponent dependent upon the variation of cylinder-condensation with the rate of expansion; and n is the exponent of v in the approximate equations of pressures and volumes $p\, v^n$ = constant = $p_1\, v_1^{\,n}$.

When $b = 1$ and $q = 0$, the equation presented above reduces to

$$y = x \frac{n - r^{1-n}}{n - 1};$$

which is the equation of the curve of efficiency for adiabatic expansion. The value of b usually falls between 0·8 and 0·9 and that of q between — 0·3 and — 0·1, sometimes becoming nearly 0.

In this new theory of the steam engine, it is seen, the quantity of steam used is to be calculated as for adiabatic expansion, and the amount thus given multiplied by $\frac{1}{b\, r^{-q}}$ to obtain the quantity actually demanded in non-adiabatic expansion.

The work done per stroke or per unit of weight of steam being calculated for the adiabatic case

$$W_a = p_1\, v_1 \frac{n - r^{1-n}}{n - 1},$$

it is obtained for real engines by multiplying by the factor $b\, r^q$, and we have for net work done,

$$W_n = {}_{pb}{}^{I}\; v_1 \frac{n\, r^q - r^{1-n+q}}{n - 1} - p_b\, r\, v_1 = \frac{b\, p_1\, v_2\, n\, r^{q-1} - r^{q-n}}{n - 1} - p_b\, v_2.$$

* "On the Several Efficiencies of the Steam Engine," etc.

The actual efficiency of any engine thus is less than that calculated for the ideal case in the proportion of $b\, r^q$ to 1.

The "General Equation of Steam Engine Efficiency," as the writer has called it, was shown to be obtained by determining the ratio of the total of annual variable costs to the power obtained from the engine

$$\frac{1}{E} = \frac{A\, r\, v_1 + B\, v}{2\, R\, W_n} = \frac{A\, v_2 + B\, v_2\, r^{-1}}{2\, R\, W_n}$$

which is a minimum when $\frac{M + r^{-1}}{W_n}$ is a minimum, A being the measure of annual costs, variable with volume of steam supplied, and $M = \frac{A}{B}$. W_n is the work done per stroke of the engine and R the number of revolutions per annum.

The value of W_n may be obtained by multiplying the value of W_n for adiabatic expansion, such as would be obtained in a non-conducting cylinder, by a factor variable with the ratio of expansion, as has been shown, which shall measure the ratio of actual work done in the metal cylinder to that done in adiabatic expansion, thus: Let b represent the proportion of steam present when expansion commences, as determined by the amount of cylinder condensation; let r^q represent the rate of variation of losses with increase of the ratio of expansion; and let n be the index for the actual expansion line of the mixture, to be determined, if possible, by experiment. Then we shall have:

$$W_n = 2\, R \left(b\, p_1\, v_2 \frac{n\, r^{-1} - r^{-n}}{n - 1}\, r^q - p_b\, v_2 \right)$$

"The General Equation of all Steam Engine Efficiencies," is therefore

$$\frac{1}{E} = \frac{A\, v_2 + B\, v_2\, r^{-1}}{2\, R \left(b\, p_1\, v_2 \frac{n\, r^{-1} - r^{-n}}{n - 1}\, r^q - p_b\, v_2 \right)} \qquad \text{(A)}$$

which becomes a minimum, and makes the *commercial efficiency* of an engine doing the required work a maximum when, to obtain r, we have made

$$r^q + \frac{q}{M(q-1)}\, r^{q-1} - \frac{q-n}{n\,(q-1)}\, r^{q-n+1} - \frac{q-n+1}{M\, n\,(q-1)}\, r^{q-n} = \frac{n-1}{M\, n\, b\,(q-1)}\, \frac{p_b}{p_1} \qquad \text{(B)}$$

The ratio $\frac{p_b}{p_1}$ is the quotient of the total back pressure by initial pressure, all useless resistance being included in p_b.

When instead of M, N is inserted in the equation, N being the quotient of *all* annual expenses, independent of fuel supply, by all such expenses variable with fuel and steam supply — the expression determines the ratio of expansion at "maximum efficiency of capital invested in a *given plant*."

When M or N is made zero, the expression reduces to:

$$\left(r^{q-1} - \frac{q+1-n}{q\,n} r^{q-n}\right) \div \frac{n-1}{b\,q\,n} = \frac{p_b}{p_1} \qquad \text{(C)}$$

and gives the ratio of expansion at which maximum "duty" or "efficiency of engine" is attained.

When $b = 1$ and $q = 0$, the case becomes that of the ideal engine working the fluid in a non-conducting cylinder, and these equations become, for efficiency of capital and of engine,

$$r^{-n} - \left\{\begin{matrix} M \\ \text{or} \\ N \end{matrix}\right\} \frac{n - n\,r^{1-n}}{n-1} = \frac{p_b}{p_1} \qquad \text{(D)}$$

$$r^{-n} = \frac{p_b}{p_1} \qquad \text{(E)}$$

Studying these equations, it will be seen that, in all except the last (E), it is possible to find finite values of r such that their left-hand members shall reduce to zero; as in them n is nearly always equal to unity; q varies from $q = 0$ to $q = {}^{-}0{\cdot}3$ in good practice, and b usually ranges between $b = 0{\cdot}8$ and $b = 0{\cdot}9$; M or N is usually between $0{\cdot}02$ and $0{\cdot}15$, and the form of the function is such that the first member may always be made to disappear for some finite value of r. Then we shall have in (B)

$$r^q + \frac{q\,r^{q-1}}{M(q-1)} - \frac{(q-n)r^{q-n+1}}{n\,(q-1)} - \frac{q-n+1)}{M\,n\,(q-1)} = o; \qquad \text{(F)}$$

and in (C)

$$r^{-n} - M\frac{n - n\,r^{1-n}}{n-1} = o \qquad \text{(G)}$$

$\frac{p_b}{p_1} = o;\ \frac{p_1}{p_b} = \infty$ and the value of r, at which this condition is obtained, constitutes an "absolute limit," for the care taken, beyond which expansion cannot be carried economically, even with steam increased to

infinite tension; beyond this point $\frac{p_b}{p_1}$ becomes negative, indicating the assumption of impossible conditions.

This is most plainly exhibited by equation (D). When the value of r is unity the second term disappears, as r increases; the magnitude of the whole term increases ($n > 1$), and passing through the value obtained from (F), the sign of the first member changes at some finite value of r, indicating, as above stated, the introduction of impossible conditions, since the sign of the second member must always be positive for any actual engine.

Examining equation (E), we find no such limit; the sign of the first member remains positive for all values of r, and can never become zero for a finite value of that quantity. We are thus taught that an important difference exists between the *ideal* engine, with its non-conducting cylinder, and the *real* engine working steam in a metallic cylinder, as well as between the case of maximum efficiency of engine and that of maximum efficiency of capital. In the cases of maximum efficiency of fluid and of engine for the ideal perfect engine, equation (E) only, is it true that indefinite increase of steam pressure permits indefinitely increased expansion. In all other cases an absolute limit exists, fixed for each case, beyond which expansion cannot be economically carried.

The above equations for real engines are approximate, and are practically exact—the values of the constants being determined with accuracy—within the range met with in practice, and the conclusions here deduced are, therefore, correct, although the exact values of the constants, or even the precise form of the variable function, r^q, here may not be fully ascertained.

Should it seem desirable, it is easy to deduce the same conclusions—and thus to confirm, by independent proof, the above proposition—by the examination of the "Curves of Efficiency" of ideal and of real engines. Thus:

Let the curve ABO be the "Curve of Efficiency" for the ideal perfect engine; let the curves CH, DG, EF be those obtained from real engines as indicated by the writers in earlier papers. Then if the ratio $\frac{p_b}{p_1} = o$ and $\frac{p_1}{p_b} = \infty$ the back pressure line coincides with base-line

* With such curves the ordinates measure the work done at various ratios of expansion in any given engine, by quantities of steam proportional to the abscissas.

passing through OX. Using this diagram to determine the ratio of expansion at maximum efficiency of engine, we draw the tangents OP, OK, OL, OM, to the several curves, and thus determine points of tangency—N, M, to the several curves for real engines, which, under the assumed conditions, correspond to the best ratios of expansion, the ratio of work done to cost of doing it being then a maximum.

The tangent point for the *ideal* engine, of which AB is the curve, falls at O, the origin.

Thus it is seen that, while the ratio has no limit for the ideal case, it has such a limit for the real engine, and that this limit may be found at a low ratio of expansion. The writer has made this comparison for the steamers "Michigan," "Georgiana," and "Bache," for which three cases the real curves have been obtained by him,* and finds that, these curves remaining unchanged,† it is impossible economically to increase the ratio of expansion in such engines beyond three, five, and ten respectively, even with unlimited steam pressure; *i. e.*, even when $\frac{p_b}{p_1} = 0$.‡

Such a limit must evidently exist in every steam engine, since the real curve of efficiency must fall within the ideal curve, AB, and can never pass without inflection through the origin O. The proposed proof is therefore complete, both as a matter of theory and as the fruit of direct experiment. The fact proven is due to the invariable increase of cylinder condensation with increasing expansion.

It is easily seen that a similar limit exists at still lower values for the ratios of expansion at maximum commercial efficiency, and that this holds true in all engines, the ideal case, AB, included; for, in the figure take the distance OO^1 proportional to annual "cost of engine," on the scale on which OX measures the "annual cost of steam" used in the same engine without expansion, and including in these items

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* *Vide Transactions of the American Society of Mechanical Engineers*, 1882; JOURNAL OF THE FRANKLIN INSTITUTE, June, 1882.

† The form and location of these curves at very high pressures would undoubtedly be somewhat altered, but it is evident that there must still be found this absolute limit so long as condensation increases with extended expansion. The writer is inclined to believe that the form of the curves will be substantially as shown, however, at any attainable pressure.

‡ The "Michigan" has an unjacketed condensing engine, using saturated steam the "Georgiana" a similar class of engine, with superheated steam; the "Bache's"; engine is jacketed and compound.

all quantities variable proportionally with each explained by the writer in earlier papers. Then tangents drawn from O^1 to the several curves as O^1P^1, O^1K^1, O^1N^1, and O^1M^1, will determine points of tangency $P,^1K^1$, $N,^1M_1$, which correspond with such expenditures of steam and such ratios of expansion as will give maximum economy of money and minimum annual expense. It is seen by inspection of the diagram that for every case a finite value of the ratio may be obtained even at the limit at which the value of $\frac{p_1}{p_b} = \infty$ and that with any engine, however perfect, there exist values of the ratios of expansion at maximum efficiency of capital, beyond which it will not pay to carry the point of cut-off, however great the steam pressure; an infinite pressure permits only a finite expansion.

We may therefore conclude:

(1) That in all engines there exists an "absolute limit to the economical expansion of steam," whether considered with reference to efficiency of fluid, of engine, or of capital, which limit can not be passed, whatever pressure of steam may be carried up to the point of cut-off.

(2) That this limit is found at higher ratios of expansion as the type of engine is more efficient, but that the limit is indefinitely removed only in the ideal engine, and then only as affecting the ratios of expansion at maximum efficiency of fluid and engine.

(3) That this limit is found at a small value of the rates of expansion in ordinary engines, and therefore may be readily passed in everyday practice.

The limit is not far from three in the common unjacketed condensing engine, four or five in the same engine using superheated steam, and ten or twelve in the ordinary compound engine.

(4) It is evident that the general propositions of this paper are true of all heat engines having fluid working substances, whether vapors or gases worked in metallic cylinders.

Hoboken, N. J., March, 1882.

OBSERVATIONS WITH THE PLATINUM-WATER PYROMETER, WITH HEAT-CARRIERS OF PLATINUM, AND OF IRON ENCASED WITH PLATINUM.

By J. C. HOADLEY.

The observations given in detail in the subjoined table indicate that the several values assigned to the specific heat of both platinum and iron, in the tables given in my paper read before the A. S. M. E. at the Philadelphia meeting, and published in the JOURNAL OF THE FRANKLIN INSTITUTE for August, are, at the least, pretty nearly consistent with each other. The platinum heat-carrier used was: (1) 1 ball, 1·1385 in. diameter, weighing 4200 grains, = 0·6 lb. avoirdupois, and having, at the assumed specific heat of $0{\cdot}03\dot{3}\dot{3}$ (= $\frac{1}{3}$ of the specific heat of of water) a calorific capacity equal to $\frac{1}{100}$ of that of 2 lbs. of cold water; or

(2) 2 platinum balls, one 0·9945 in. diameter, weighing 2800 grains, =0·4 lb. and an assumed capacity equal to $\frac{1}{150}$ of that of 2 lbs. of water; the other 0·7894 in. diameter, weighing 1400 grains, = 0·2 lb. and having an assumed heat capacity equal to $\frac{1}{300}$ of that of 2 lbs. of cold water. The two smaller balls together were, therefore, equal to the larger one alone.

The platinum and iron heat-carriers were two balls, alike, about 0·98 in. diameter outside, having a core of wrought iron weighing 700 grains encased in a solid capsule of platinum also weighing 700 grains. Of each metal there is, therefore, 0·1 lb. At the assumed specific heat of $\frac{1}{30}$ for Pt and $\frac{1}{6}$ for Fe, the heat capacity of the latter is five times as great as that of the former, and the combined heat capacity is equal to that of 0·6 lb. of platinum, and to $\frac{1}{100}$ of 2 lbs. of cold water.

By means of a table constructed on the same plan as the one in my paper above referred to, and to be used in the same manner, suitable corrections may be made for observations with these composite Pt and Fe balls as readily as for platinum alone.

It further appears that in the absence of platinum, or of iron balls coated with that metal, a lump of iron may be used, by the application of the proper specific heat at the observed temperature, and will give a

TABLE 1.

Pyrometric Observations in the Furnace of a Steam Boiler, by the Platinum-Water Pyrometer, with heat-carriers of platinum, and of iron (700 grains), covered with platinum (700 grains). Water, 2 lbs. + for heat capacity of the cup, 0·1053 *lbs.* = 2·1053 *lbs. Assumed ratio,* 105·265 *to* 1. *Assumed specific heat,* $Pt = \frac{1}{30}$, $Fe = \frac{1}{6}$ *of* H_2O.

No.	Observed temperatures of water in pyrometer, deg. F.	British thermal units contained in water at observed temperatures.	Heat-carrier. Kind of metal.	Heat-carrier. Ratio of water to heat carrier.	Observed loss of heat by heat-carrier in cooling, deg. F.	Corrected loss of temperature, and true temp. of heat-carrier.
1	96·65 81·20	96·71195 81·23740	Pt	105·265	1628·9	1487·6 96·7
	15·45	15·47455				1584·3
2	99·3 83·4	99·3779 83 4438	Pt	105·265	1677·3	1526·7 99·3
	15·9	15·9341				1626·0
3	102·51 85·40	102·59753 85·44580	Pt and Fe	105·265	1805·5	1496·8 102·5
	17·11	17·15173				1599·3
4	103·02 86·16	103·10906 86·20732	Pt and Fe	105·265	1779·2	1483·1 103·0
	16·86	16·90174				1586·1
5	110·30 81·54	110·41098 81·57808	Pt	105·265	3035·1	2546·0 110·3
	28·76	28·83282				2656·3
6	113· 81·	113·121 81·037	Pt	107·7	3446·4	2822·4 113·0
	32·	32·084				2935·4

NOTE.—In Obs. 6 the platinum balls were partially fused, and 1017 grains ran off and cooled in drops like shot, sometimes several drops congealed together. One drop, weighing 95 grains, adhered to the exterior of the cup, and did not enter the water. This circumstance raised the ratio from 105·265 to 1, to 107·7 to 1.

The mean of Obs. 1 and 2 is $\frac{1584{\cdot}3 + 1626{\cdot}0}{2} = 1605{\cdot}2°$

The mean of Obs. 3 and 4 is $\frac{1599{\cdot}3 + 1596{\cdot}1}{2} = 1592{\cdot}7°$

The mean of Obs. 1, 2, 3 and 4 is $\frac{1605{\cdot}2 + 1592{\cdot}7}{2} = 1599.°$

TABLE 2.

True temperatures in degrees Fahr. corresponding with observed temperatures in columns 2, 5 and 8.	Observed loss of temperature by platinum heat-carrier at assumed ratio of specific heat H_2O to Pt as 30 to 1.	Differences of loss for each 100 degrees. First difference.	Differences of loss for each 100 degrees. Second difference.	Observed loss of temperature by iron heat-carrier at assumed ratio of specific heat H_2O to Pt as 6 to 1.	Differences of loss for each 100 degrees. First difference.	Differences of loss for each 100 degrees. Second difference.	Observed loss of temperature by Pt and Fe heat-carrier at assumed ratios of specific heat Pt $\frac{1}{30}$, Fe $\frac{1}{6}$.	Differences of loss for each 100 degrees. First difference.	Differences of loss for each 100 degrees. Second difference.
1	2	3	4	5	6	7	8	9	10
0	0·			0·			0·		
32	30·8	96·9		20·5	65·5		22·2	70·7	
100	96·9		1·7	65·5		4·5	70·7		4·1
		98·6			70·0			74·8	
200	195·5		1·9	135·5		5·3	145·5		4·7
212	207·5	100·5		144·2	75·3		154·8	79·5	
300	296·0		1·8	210·8		6·3	225·0		5·6
		102·3			81·6			85·1	
400	398·3		1·8	292·4		7·1	310·1		6·1
446·2	446·2	104·1			88·7			91·2	
500	502·4		1·9	381·1		7·8	401·3		6·9
		106·0			96·5			98·1	
600	608·4		1·8	477·6		8·9	499·4		7·7
		107·8			105·4			105·8	
700	716·2		1·8	583·0		9·6	605·2		8·3
		109·6			115·0			114·1	
800	825·8		1·8	698 0		10·6	719·3		9·1
		111·4			125·6			123·2	
900	937·2		1·8	823·6		11·2	842·5		9·7
		113·2			136·8			132·9	
1000	1050·4		1·9	960·4		12·3	975·4		10·5
1060	1119·5			1048·4			1060·2		
		115·1			149·1			143·4	
1082·5	1145·9			1082·5			1093·1		
						13·1			11·3
1100	1165·5		1·8	1109·5			1118·8		
		116·9			162·2			154·7	
1200	1282·4		1·8	1271·7		13·9	1273·5		11·8
		118·7			176·1			166·5	
1300	1401·1		1·9	1447·8		14·8	1440·0		12·7
		120·6			190·9			179·2	
1400	1521·7		1·8	1638·7		15·6	1619·2		13·3
		122·4			206·5			192·5	
1500	1644·1		1·9	1845·2		16·5	1811·7		14·0
		124·3			223·0			206·5	
1600	1768·4		1·8	2068·2		17·4	2018·2		14·9
		126·1			240.4			221·4	
1700	1894·5		1·8	2308·6		18·2	2239·6		15·4
		127·9			258·6			236·8	
1800	2022·4		1·8	2567·2		19·1	2476·4		16·2
		129·7			277·7			253·0	
1900	2152·1		2·0	2844·9		19·9	2729·4		17·0
		131·7			297·6			270·0	
2000	2283·8			3142·5			2999·4		

reasonable approximation to accuracy. Very delicate thermometers are necessary to accuracy, where 1° represents 100°.

Careful weighing of the iron, both before and after use, would be required to detect loss by oxidation. The nearer the spherical form the better, as the loss would be at the surface. At best, the results with any other metal than platinum can be only roughly approximate, and can be carried only up to about 1200°F.; and even with platinum itself there must be a margin of uncertainty—at present. For convenience of using platinum and iron, or simple iron heat-carriers, I give, in Table, 2 the corrections for platinum, for iron, and for the two metals combined in equal weights as above explained, computed in the manner already described, and to be used as indicated in this communication. By means of the columns of differences (the 1st differences alone need be used) the table will be found of easy application.

ERRATA.—The author regrets that in consequence of a necessarily hasty correction of a galley proof, without opportunity for revision, some errors in his article on the Specific Heat of Platinum in the issue of this journal for August escaped his notice. These are corrected in the following errata.

P. 92, l. 15, for $h_t = t\,(a + bt + ct. \ldots.)$, read $h_t = t\,(a + bt + ct^2 + \ldots$ etc.).

P. 95, tables, transpose the Means for 800° and 1000°, *i. e.* for ·03758, read ·03645; for ·03645, read ·03758.

P. 96, l. 16, for $0.3\dot{3}\dot{3}$, read $.03\dot{3}\dot{3}$; l. 22, for .00003728, read .00009728; bottom line, for k_v, read k_t.

P. 97, first line of tables, col. 6, for —1·3, read ·0; col. 7, for 98·2, read 96·9; next to last line, col. 6, for 184·5, read 1894·5; col. 7, for 127·8, read 127·9.

PP. 97, 98, heading of col. 6, for Observed temperatures by pyrometer at assumed ratio: w. to pt. ball 100 to 1, read "Observed loss of temperature by platinum at assumed ratio of sp. ht. 30 to 1."

Note.—From the observed loss of temperature in column 6, find the corresponding *true* loss, in column 1, and to this add the temperature of the water in pyrometer after the immersion of the platinum, to obtain the true temperature of the platinam at immersion.

THE MICROSCOPE IN ENGINEERING WORK.

By Robert Grimshaw.

[A paper read at the Stated Meeting of the Franklin Institute, June 21, 1882.]

The specimens shown are intended to outline a method of using the microscope as an aid to the testing machine in estimating the value of structural materials.

While it is not intended to suggest that the microscope will determine definitely the elastic limit, nor even the breaking strain of structural materials, it is designed to convey very distinctly the idea that the microscope may be used for preliminary investigations which will determine whether or not the material is good enough to warrant its being tried on the testing machine. If the microscope condemns the material, it is not worth while going to the expense of having it tested by more expensive methods. If the microscope fail to reveal any flaw, then the material may be sent to the testing machine to be further proved. The larger the specimens that would be required for testing in the machine, the more marked the advantages of the microscope in saving, in the case of specimens readily determined to be bad, the expense of further testing, and the risk of using it in construction. The samples shown this evening are of bridge timbers, and the lesson they are intended to convey is that had this method of examination been followed, the material which was proved to be faulty after being built into the bridge, would have been promptly thrown out.

The samples shown were photographed by Mr. W. E. Partridge of New York, a professional engineer who is an enthusiastic amateur photographer, and to whom I am indebted for the particulars concerning them.

"The timber from which the poor specimens were taken came in the form of a chip broken off when a highway bridge was wrecked in 1879–80. The timber formed a portion of the sill of a draw-bridge, which consisted of two twelve-inch sticks, lying one on the other. The turn-table casting having been somewhat too small, this twenty-four-inch timber had to support one of the A frames of the bridge at a distance of twelve inches outside of the bed-plate. After a few days of service, while an empty truck was passing over, the strain became so

great that the A frame sheared the twenty-four inch sill, wrecking the whole bridge. The timber was so exceedingly poor that upon mounting it on the microscope the porous and weak nature of its structure was at once discovered. Its annular rings are something like three times the distance apart which would be found in a piece of thoroughly good wood of a similar character. The medullary rays are few in number and short in length, while in good wood they are of considerable length, and so numerous that the tangential sections appear like a series of tubes seen endwise or a number of parallel chains. After once seeing and comparing two samples of wood it is very easy to recognize their characteristic features by the use of a pocket magnifying glass."

The trunks and limbs of exogenous trees are built up of concentric rings or layers of woody fibre, which are held together by radial plates acting like the trenails of a wooden vessel, or the "bonds" in a brick or stone wall. The rings or layers, representing successive years' growths, are composed of tubes, the interstices between which are also filled with cellulose. The slower the growth of a tree, the thinner these yearly layers, and the denser and harder the wood,—other things being equal. This is true as between one kind of tree and another, and also as between different individuals of the same kind.

Not only is the closeness of the growth an indication of the hardness and strength of the timber, but the size, frequency, and regularity of distribution of the radial plates which bind the layers together may be taken as a very close illustration or sign of the character of the wood and its ability to resist strain, especially that from crushing stress.

The micro-photographs of the sections of good and bad timber show that in the strong specimens the concentric rings are close in texture and of slight width; and the radial plates frequent, wide, long, and thick, while in the poor material, the reverse characteristics are shown.

The lesson to be learned from these micro-photographs is that having proper views of transverse and radial lengthwise sections, and of sections perpendicular to a radius, of a standard piece of timber resisting certain standard or minimum strains,—all timber having fewer rings per inch of tree diameter, fewer fibres, and fewer and shorter radial plates per square inch of section, should be rejected as not up to the standard, and applied for other purposes or used with a greater factor of safety.

This method has the advantage of enabling every stick of timber in a bridge to be inspected and judged, and is offered as an interesting and valuable aid to the breaking tests made by the machine.

In this connection, I may offer as the parallel in metal work two portions of pure Lake copper; one an ingot as ordinarily found, in which the grain is coarse and crystalline, the color dark-red, and the mass full of blow-holes; this is an average sample of copper casting. The other is run from the same pig, at the same heat, and in a similar mould, but with proper precautions to prevent oxidization; in consequence, there are no blow-holes, the grain is close and fine like that of the best bronzes, and the color is *salmon*, which is the true copper color. The "deoxidized" casting weighs 25 per cent. more than the ordinary casting from the same pattern, calipering the same. For these I am indebted to the Philadelphia Smelting works, Twelfth and Noble sts.

Tests made of the deoxidized copper rolled into sheets ·035 inch thick showed on strips 2 inches wide a tensile strength of 33,760 pounds per square inch, ordinary fine copper in sheets being quoted by Trautwine at 30,000 pounds. This would show 12·5 per cent. superiority in the metal having the fine fracture.

No. 20 "deoxidized" wire shows a calculated tensile strength of 45,000 pounds per square inch, and still later tests of wire of the same thickness showed a calculated tensile strength of 41,056 pounds per square inch for the ordinary, and 47,552 pounds for the deoxidized,* a striking confirmation of the indications of the microscope.

Transmission of Force to Great Distances.—Emile Lacoine shows that the distance to which a dynamo machine can transmit any given fraction of its energy is inversely proportional to the square of the section of the enrolled wire, and the temperature of the conductor is raised much less in proportion as the distance increases.—*L'Electricien.* C.

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* Actual breaking strength of the wires, 39½ and 39½ pounds for two samples of the "commercial," and 44½ and 47 pounds for the "deoxidized." It must be remembered that the larger the specimens tested the lower the tensile strength per square inch of section, and the finer the wire is drawn the greater its tensile strength per square inch, and the less the superiority of the metal which was close-grained in the ingot.

TESTS OF DOUBLE RAW HIDE BELTS.

By John E. Hilleary.

[A paper read at the Stated Meeting of the Franklin Institute, May 17, 1882.]

Having made some tests of new riveted double so-called "raw hide" (semi-tanned and fulled) belts on a 36-inch new wooden pulley, with 180° arc of contact and tensions of 25 and 50 pounds per inch of belt width, I find them as follows:

With the grain side next the pulley (both grain sides were out, as is usual with tanned leather belts) the grip with 25 pounds tension per inch was 200 pounds, and with 50 pounds, 460 pounds. It thus seems that in the case of this 4-inch new double-fulled leather belt, on that new 36-inch wooden pulley, with 180° arc of contact, doubling the tension more than doubled the grip, the latter being as 100 to 230.

Comparing the grip of the double belt with that of a single belt of the same material, under the same conditions (grain side to), we find as follows:

	Single.	Double.	Ratio show- influence of thick- ness.
25 pounds tension per inch . .	300	200	$0{\cdot}66\frac{2}{3}$
50 " " .	400	460	1·15
Ratio showing influence of tension......	1·33	2·30	....

These results are curious, and would indicate, without looking into the matter, that with new riveted double "fulled" belts on 36-inch new wooden pulleys, with 180° contact and tensions of 25 and 50 pounds per inch width—

(1) With light tensions a double belt will not grip as well as a single one.

(2) With heavy tensions a double belt will drive more than a single one.

(3) Both single and double belts drive better with heavy than with light tensions.

(4) The influence of tension is more marked with double than with single belts.

In reference to "raw hide" belts there are some that get hard after running a while, while others remain pliable and elastic. By "elastic" I do not mean that they stretch so as to necessitate being taking up constantly; for a belt that needs taking up every little while is not elastic. If it were elastic, the local extension in length while in contact with the pulley would be counteracted in each portion as soon as it got round to slack side.

I want to be particularly understood as repudiating, as yet, any general formulæ or statements covering the working of belts on pulleys where all the conditions are not stated. Some of my notes may seem to contain needless repetitions, but they are cautionary limitations. If, after making my tests of new single leather belts on new cast-iron pulleys, I had formulated the rule that new leather belts drive best flesh side to the pulley, I should have been badly "out" on the subject of semi-tanned leather belts.

New Determination of Joule's Equivalent.—Cantoni and Gerosa have determined the mechanical equivalent of heat by a series of experiments in which they substituted mercury for water. Its great thermal conductibility, and the relative invariability of its specific heat at the low temperatures which they employed, induced them to make the substitution. The method of experimenting consisted in the sudden arrest of a mass of mercury, falling from a given height and consequently provided with a known amount of dynamic energy. The increase of temperature at each experiment was carefully measured, and the dynamic equivalent of caloric deduced by a simple calculation. The mean of all the results is almost precisely the same as that which Joule obtained from his most satisfactory experiments. The agreement of the values which are furnished by two processes that are so distinct seems to give complete assurance of the accuracy of the results. C.

GREATEST RINGING BELLS.

By John W. Nystrom.

Russia is famous for having the greatest bells in the world, but if the great *Tzar Kolokol* of Moscow, which has never served the purpose of a bell, be excluded, then Burmah takes the honor of having the largest ringing bells.

Burmah Bells.

The Burmah bell founders appear to have attained great perfection in that art, and they take great pride in their productions. The quality of tone of the Burmah bells are said to be very fine. The Mengoon bell is the greatest ringing bell in the world, weighing 201,600 pounds, and its probable diameter is 203 inches.

The great bell in Rangoon, called "*Maha Ganda*," weighs 95,000 pounds, with probable diameter of 155 inches, is said to have a very fine tone.

Russian Bells.

The first great bell in Moscow was presented to St. Ivan's Church by the Tzar Boris Godunof, in the sixteenth century. This bell was actually hung and rung, but its weight, 288,000 pounds, was too great for its support, it fell and broke and was recast in the year 1654. Diameter, 216 inches, and soundbow 18 inches. During the fire in 1706 the bell fell and broke again.

The greatest bell in the world is that at Moscow, called *Tzar Kolokol*, or monarch bell. Its dimensions are 19 feet 3 inches high, diameter 22 feet 8 inches, thickness of soundbow nearly 2 feet, and weighs 443,772 pounds. The weight has evidently been calculated, because the Russians had no scale upon which it could be weighed. From the dimensions of the bell, taken by the writer and the weight calculated, it should weigh nearly 500,000 pounds.

According to inscription on the bell, it was cast in the year 1733. In those days they had no means of transporting heavy weights and great bells were, therefore, cast in the churchyards close to where the bell was to be hung, as was the case with the great Moscow bell, which was cast in a pit close to St. Ivan's Church, in which tower it was intended to be hung.

The moulding of the bell was probably done in the ordinary way, namely, the core was built first, upon which the thickness of metal was laid with loam or clay, and the cope built over it. Judging from the unevenness of the inside surface of the bell, it is probable that the core was not swept but dubbed up, so that the bell is not of even thickness at equal distances from the lip. The outside surface is very even, and has evidently been swept by a steady sweep.

In preparing and melting the metal for casting the bell it appears that no exact composition was attempted, for the nobles and other capitalists of Moscow threw a great amount of silver and other metal into the furnace, which made it an uncertain alloy with much greater shrinkage than the minimum, which is, with 31 parts of tin to 100 of copper.

The moulding, casting and precautions for cooling and shrinkage of a bell of this size require more practical experience than probably these bellfounders were in possession of, for it is evident that the bell broke by shrinkage in the pit in which it was cast.

The cooling of a bell of this size requires a time of at least one month if not six weeks, from the day it was cast, but it appears that the bell founders attempted to dig up the bell a few days or a week after it was cast; and it is also said that water was poured on the mould or casting; at all events, the bell was cooled too quickly and cracked in several places around the lip, and in one place a piece weighing about 11 tons was broken off. The uneven thickness of metal also aided the breaking.

The great Moscow bell has, therefore, never been sounded, but laid in its casting-pit, partly uncovered, for a time of 103 years, in which time it was held in reverence by the natives who were extremely jealous of its being touched or measured by strangers. Thus it laid as an object of wonder to travelers, and the people of Moscow visited it with pride at their festivals.

In the year 1836 the Emperor Nicholas decided to have the bell exhumed and raised, which was accomplished with great difficulty and expense. The engineers who first undertook to raise the bell were not given a fair chance to accomplish the work, because on their first trial the tackle were too light and gave way, for which the engineers, it is said were sent to the mines of Siberia.

The board of admiralty then undertook to raise the bell, and succeeded in placing it in the position as shown in the accompanying illustration, which is reduced from a large photograph procured by the writer in

Moscow, in the year 1871. The bell is placed south of St. Ivan's Church, on an open plazza in the Kremlin, near to where it was cast.

It is said that the Empress Anne presented the bell to the church, but however that may be, it is known that the fragments of the bell which fell and broke in 1706 were used; and the citizens of Moscow contributed largely to the metal in the bell which contains much silver and some gold. It is said that the value of the metal in the bell is $332,000, all uncirculating and dead money, for the bell has never struck a note.

"Think of that, ye money-mongers on the Rialto," says Rev. Alfred Gatty.

In some records of the great Moscow bell it is stated that the bell was actually hung and rung in the tower of St. Ivan's Church, and that it had been broken by falling to the ground. It is also stated that the building over the casting pit took fire after the bell was cast, and the water used for putting out the fire fell on the bell in the pit and caused its breaking. But these records have been contradicted by competent judges.

Tzar Kolokol.—Description of the Plate.

The accompanying plate, representing the "Bolshoy Tzar Kolokol," is produced by the phototype process invented by Mr. C. H. Jacobi, of Neuendorf-Coblentz, and now used exclusively by Mr. F. Gutekunst, 712 Arch street, Philadelphia. This process (with others allied to it) is one of the great achievements of recent times. With its aid a view can be taken from nature and as many copies as desired may be reproduced in the printing-press, preserving the softness of a photograph, the permanency of a steel-engraving and the absolutely correct representation of the original object. The illustration has never been touched by any handwork or artistic skill, but a negative taken from my photograph by which the printing-plate was prepared. This process is well known and widely used in Germany, and will, no doubt, be so also in America, for it has fortunately fallen into good hands.

The great Moscow bell, as represented on the plate, rests on a granite pedestal with its broken off piece on the ground. The enormous size of the bell can be perceived by the proportionate size of the men standing at the foot of it and by the size of the cathedral behind. The St. Ivan's

Phototype, F. Gutekunst, Phila.

GREAT BELL OF MOSCOW.

FOUNDED 1733.

Height 21 ft. $4\frac{1}{2}$ in. Diameter 22 ft. 8 in. Weight 198 tons.

Church, in which tower the other large bells hang, is close by to the right of Tzar Kolokol, but not shown on the plate.

The scale of the bell represented on the plate is 8·095 feet to the inch, in the plan passing through the axis of of the bell and parallel with the plate; but that scale will not be correct for measuring the height of the men in front of the bell, because they were 13 to 14 feet nearer to the camera obscura when the photograph was taken, and they therefore appear larger by that scale. The same is the case with the broken off piece on the ground, which by scale measurement is larger than the hole in the bell from which the piece was broken. The church on the other side of the bell is larger than the scale measurement. The axis of the photographic instrument was placed level with the lip of the bell.

The female figure in base relief on the left side of the *latus* represents the Virgin, and the inscription is on the right side towards St. Ivan's Church. The uneven thickness of metal, at equal distances from the lip, can be seen and measured at the top of the broken off piece on the ground. The form of the bell and its base relief ornaments are master pieces of fine arts. Omitting the accidental unevenness of thickness, the proportions of the bell indicate that its constructor understood the acoustic properties of the vibrating metal when a bell is tolled.

Our modern celebrated bell founders are far behind that constructor in proportioning bells for quality of sound. I should like very much to see the Tzar Kolokol recast the same size, and the form and ornaments exactly preserved. With our present knowledge and experience in founding the recast bell would be a success.

The other great bells in Moscow and other places are noted in the accompanying table, in their order of sizes.

The Russians have generally a great number of bells of different sizes in their churches, but they are not toned for musical harmony or melody, and their ringing is not agreeable to strangers, who often make severe remarks upon their noise. During my five years in Russia I could never get accustomed to or appreciate the bell-ringing, which is a disagreeable jangling.

The great bell in St. Ivan's Church is rung three times a year, and produces a tremulous effect throughout the city, like a distant thunder or the low notes on a powerful organ.

The old bells of Russia are much better in tone than modern bells cast in Moscow 25 years ago or thereabout, but I have information that they make better bells now.

The Russians never swing their bells, but hang them stationary, and even the smallest church bells are rung by ropes attached to the clappers.

CHINESE BELLS.

China is next in order of great bells, but their awkward form and projecting ornaments make them far inferior in tone to our bells.

The great bell in Pekin weighs 120,000 pounds, diameter 13 feet, and height 14 feet 6 inches. It is rung by one man striking its outside by a wooden mallet. An ordinary iron clapper would probably break the bell on account of its irregular distribution of metal.

The great bell of Nankin weighs 45,000 pounds. Large bells are very common in all cities of China, but all bad in tone, and chime ringing is unknown there. The construction of China bells shows absolute ignorance of the science of acoustics as applied to that art.

JAPANESE BELLS.

In Japan, ringing bells are very common, and are a little better than those in China. They make the bells cylindrical, with a spherical top, and ring them by a weight hung on a rope striking the bell outside.

The Chinese and Japanese bells require double the amount of metal for the same volume of sound produced by our bells.

The ancient literature, that is, from the year 1495 to the end of the last century, was rich on bells, and the subject was treated by able scientific men. A civil judge, Maginus Tintunatius, in the Venetian service at Candia, when besieged by the Turks in the year 1571, was taken prisoner, and in his captivity amused himself by writing a treatise on bells, which is said to be the best written on that subject; but, as the Turks considered the bell as a symbol of sinful infidelity, the author was beheaded by the order of a pasha. The manuscript was, however, preserved and published, by which his name is immortal.

When the Turks took Constantinople, in 1453, they forbade the ringing of bells, for the purpose of preventing signals being given for popular revolt.

The art of bell founding has not advanced in this century, but has gone backwards in many cases, which proves conclusively that a good bell cannot be produced by practical experience alone, but a scientific knowledge of acoustics is necessary with experience, not only for making a good bell, but also for producing the maximum volume of sound with the minimum quantity of metal.

The Largest Ringing Bells in the World.

Names and Location of Bells	Date Cast.	Actual Vibrat	Key-note.	Diam. Inches	Soundbow. Inches	Stroke.	Weight Pounds
Moscow, Tzar Kolokol........	1733	74	D	272	23	0·84	443,772
Burmah, Mengoon.............	....	94	F♯	203?	16?	0·80	201,600
Moscow, St. Ivans.............	1819	105	G♯	185	14·75	0·80	127,350
Pekin, Great Bell.............	....	....	....	156	....	....	120,000
Burmah, Maha Ganda.......	....	125	B	155	12·5	0·80	95,000
Nishni, Novgorod.............	....	125	B	151	12	0·80	69,664
Moscow, Church Redeemer	1879	141	C♯	136·3?	10·6	0·80	60,736
Nankin, China.................	....	....	....	112	....	....	45,000
London, St. Pauls.............	1881	157	E♭	114·25	8·75	0.76	42,000
Olmutz, Bohemia.............	....	157	E♭	121	9·125	0·75	40,320
Vienna, Austria................	1711	157	E♭	118	9·5	0·80	40,200
Westminster, London........	1856	166	E	113·5	9·375	0·83	35,620
Erfurt, Saxony..................	1487	176	F	103·6	9·75	0·75	30,800
Notre Dame, Paris............	1680	166	E	103	7·5	0·73	28,670
Montreal, Canada.............	1847	176	F	103	7·8	0·76	28,560
York, England..................	1845	187	F♯	100	8	0·80	24,080
St. Peter, Rome................	1786	187	F♯	97·25	7·5	0·77	18,000
Great Tom, Oxford...........	1680	210	G♯	84	6·125	0·73	17,024
Cologne, Germany............	1477	198	G	95	7·2	0·76	16,016
Brussels, Belgium.............	....	210	G♯	95·81	7·75	0·71	15,848
State House, Philadelphia...	1875	198	G	88	6·375	0·73	13,000
Lincoln, England..............	1834	210	G♯	82·85	6	0·73	12,096
St. Paul's, London............	1716	222	A	81	6·08	0·75	11,500
Exeter, England	1675	210	G♯	76	5	0·66	10,080
Old Lincoln, England........	1610	249	B	75·5	5·94	0·78	9,856
Westminster, London........	1857	249	B	72	5·75	0·79	8,960

Liberty Bell.

The Liberty Bell of Philadelphia was cast over four times before it became qualified to ring-in the Independence of the United States of America. It was cast the first time by Lester & Pack, 267 Whitechapel, London, in the year 1752; brought to Philadelphia and hung in the State House the same year, but when struck for the first time it gave a droll sound, and upon examination it was found to be cracked in the rim. It was then decided to send the bell back to London and have it recast in the same foundry, but Messrs. Pass & Stow, brass founders, undertook to recast the bell in Philadelphia. The first recast bell, in 1753, did not satisfy the authorities, and a second bell was cast from the same original metal, but without the anticipated success, but it was broken up and recast a third time, when it proved successful, and twenty-three years after it rung-in this nation's independence of a foreign potentate. Its weight is 2080 pounds. In the morning of July 8, 1835, it was cracked while being tolled in memory of Chief Justice Marshall, but was still rung, with a doleful sound, until the 22d of February, 1843, when the crack increased so as to make the Liberty Bell thenceforth mute forever, though not dead. It was placed on the honorable retired list, and hung in a conspicuous place in the Hall of Independence, on duty to pay homage to visitors.

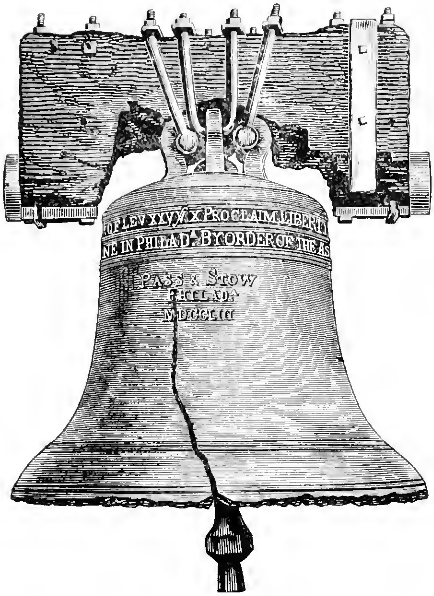
The accompanying illustration of the Liberty Bell is of a scale 0·55 of an inch to the foot.

Diameter at the lip, . . .	48 inches.
Thickness of soundbow, . .	$3\frac{1}{4}$ "
Keynote, American pitch . .	E.
Double vibrations per second, .	392.
Weight, . . .	2080 pounds.

The predestination of the Liberty Bell was inscribed with raised letters cast on it in London, 1752, as ordered by the Assembly of the Province of Pennsylvania. The same inscription was put on the recast bells by Pass & Stow, Philladelphia, 1753, namely, as follows:

"Proclaim liberty throughout the land to all the inhabitants thereof."—Levit. xxv, 10.

The predestination was realized twenty-three years after the bell was cast, when the sovereign people assembled, with the benediction, *All men are born free and independent.*



The 10th verse, chapter xxv of Leviticus reads thus: "And ye shall hallow the fiftieth year, and proclaim liberty throughout *all* the land, unto all the inhabitants thereof; it shall be a jubilee unto you." Like a flash of lightning the quotation became intelligible to every ear, and was promulgated in rhyme and prose.

Second State House Bell.

The second State House bell was cast by John Wiltbank, of Philadelphia, in the year 1828, and weighed 4600 pounds. This bell was cast over three times before proving successful, but the last one turned out to be a very good bell, and was used for fire alarm and time striking. In the year 1875 it was taken down and removed to Germantown Town Hall, where it is now doing good service by sounding time with the same old clock as used in the State House.

Third State House Bell.

The third State House bell was presented to the City of Philadelphia by Henry Seybert, Esq., on July 4, 1876. Its weight is 13,000 pounds, and was cast twice by Messrs. Menealey & Kimberly, of Troy, N. Y. The first bell, after having been hung in the State House

tower and sounded, was found to be unsatisfactory in quality of tone, whereupon it was taken down and returned to Troy for recasting. The second bell proved to be a little better, but competent judges say that it is not a good bell. Its dimensions and key-note will be found in the foregoing table. Mr. Seybert also presented to the city the clock which strikes the bell.

Westminster Bell of 1856.

The London Westminster bell of 1856 proved to be a failure, and was therefore taken down and recast the next year. The first bell weighed 35,625 pounds, and the second weighs only 8960 pounds.

There are many bells rung in different parts of the world which are much worse than some of those that have been condemned for producing bad sound.

REPORT ON EUROPEAN SEWERAGE SYSTEMS, WITH SPECIAL REFERENCE TO THE NEEDS OF THE CITY OF PHILADELPHIA.*

By Rudolph Hering, C.E.

Philadelphia, Autumn of 1881.

Samuel L. Smedley, Esq.,

Chief Engineer and Surveyor of City of Philadelphia.

Dear Sir:—In order to finally present the conclusions gained during my visit to Europe, and their application to Philadelphia, I shall group the material according to subjects, instead of to the places visited, which latter method, however, was the more expedient one to pursue for the six preliminary reports I sent you from Europe. And I shall confine myself now to the consideration of only those points which have a bearing on the existing works and future needs of our city.

The best way of treating the matter will be: To briefly state the conditions presented by our city, and allude to its present sewerage system, the details and management, in order to clearly understand in

* The author of the following report was selected by the National Board of Health to examine and report upon the sewerage works in Europe. The report we publish was prepared from facts noted and observations made while performing this duty.

what directions improvements are most desirable in the light of experience gained in other cities.

Then, it will be in place to state how the same or similar conditions have been treated elsewhere with success, referring to the general design, the details, the management and the cost, and finally to give the conclusions for our own purpose, as indicated thereby.

Before entering upon the subject I desire here to express my sincerest thanks to the gentlemen who so cordially gave me the desired information. In the many towns of England and Germany where the sewage question has received attention, as well as in Paris, Vienna and Zürich, I was met by the municipal engineers and others with the greatest courtesy, and was always cheerfully aided in my endeavor to obtain a fair knowledge of their works. And I feel under special obligations to the chief engineers and their assistants who accompanied me into or through some of their sewers, a labor sometimes not very agreeable except to those who feel the deepest interest in one of the most important branches of sanitary science.

I have attached to this report the following appendices to which occasional reference will be made.

Appendix No. 1. Area, population and dwellings of Philadelphia according to wards.

Appendix No. 2. Heaviest known rainfalls in Europe compared with Philadelphia.

Appendix No. 3. Regulations for house sewerage in Frankfort-on-the-Main, Hamburg, Berlin, Danzig and Seven-Oaks Local Board.

Appendix No. 4. Drawings of sewerage details as follows: Sections of sewers in Paris, Berlin, Vienna, Hamburg, Frankfort, Brighton and Oxford. Junctions of three sewers in Berlin and Frankfort. Overflows in Berlin, Brighton and Zürich. Manholes in Berlin, Liverpool, Frankfort and Munich. Side-entrances in Paris and Frankfort. Ventilating and flushing shafts in Frankfort and Munich. Street inlets in London, Paris, Berlin, Hamburg, Liverpool Frankfort, Brighton and Zürich. Catch-basin for debris from a sewered mountain creek in Zürich. Details for cast-iron covers for manholes, etc., egg-shaped tide-flap, foot-irons and flushing slide.

Appendix No. 5. Sewage plans of London, Paris, Berlin, Vienna, Liverpool, Hamburg, Frankfort, Oxford and Danzig.

An inquiry into the question of city sewerage discloses a marked difference of opinion regarding the best methods, and this is not simply

confined to the numerous details of the works, but even to the general systems themselves.

We find in our own country a discussion inaugurated on the propriety of leading rain-water and sewage into the same channels. One party holding that there should be two "separate" systems for this purpose, another, that there should be one, a "combined" system. A similar variance of opinion is found in England.

In Paris, the present method pursued is to lead, besides the rain-water, all ordinary house waste-water into sewers, but to exclude the excreta from four-fifths of the population, and from the remaining fifth their solid portions, which are removed in casks or by odorless excavators from cesspools, as in Philadelphia. This state, however, is not a permanent one. The municipal engineers favor complete water-carriage, and improvements in this direction are constantly made.

In Germany, the opinions are divided on the question, whether they shall remove the excreta by casks or pails, usually termed the process of "dry removal," or by sewers through "water-carriage."

Finally, there is a party advocating the so-called Liernur system, where the excreta and a certain portion of the house waste-water are led into a system of iron pipes and removed pneumatically by means of an engine at a central station. The remaining house-water is taken away with the rain-water in a separate system of brick sewers.

In examining these various systems, most of which are found to work well at certain places, and comparing the opinions given by the advocates and opponents of each, it became evident that both the advantages and disadvantages were frequently exaggerated. The true question and the one where agreement could be attained, appeared to be, not as to what method is the best *per se*, but rather, under what circumstances or external conditions each of the several good systems become the most advisable.

And herein lies, in my judgment, the solution of the general sewage question. When well designed, well built and well managed most of the systems can give satisfactory results. Yet each one will have a certain range of applicability where it has advantages over the rest, and therefore is preferable.

When wishing to adopt a system for a town, we should therefore not ask, in a general way, what system of removing offal and waste-water is the best, but, rather, which of them is most suitable to the local conditions presented by the town. And this question I shall

now endeavor to answer with reference to Philadelphia by discussing 1. What system is best applicable to Philadelphia; 2. House sewerage, 3. Street inlets or gullies; 4. Sewers; 5. Junctions, connections, overflows and outfalls; 6. Appendages to sewers for inspection, ventilation and flushing; 7. General alignment of system; 8. Management and cost; 9. Recapitulation of general conclusions.

I. What System is Best Applicable to Philadelphia?

In conformity with the method indicated, it will first be proper to review our own conditions and needs, then to examine other works under similar circumstances, and finally, to draw any conclusions that may present themselves with regard to benefiting our city.

Philadelphia lies at the confluence of the Delaware and Schuylkill rivers,* and about eighty miles above the point where the former flows into the Atlantic Ocean. The tide rises and falls six and a quarter feet, the water never becoming brackish. Near the centre of the city the Schuylkill is dammed to a height of about seven feet above ordinary high tide, the water above being used for domestic and other purposes. Four-fifths of the entire quantity of water consumed in the city is obtained from this stream, while one-fifth is taken from the Delaware River.

The pollution of our drinking water by sewers discharging into the rivers does not need examination at this place. It is only necessary to state, that the time is very near at hand, if it has not already arrived, when the indiscriminate discharge of sewage into the rivers will require some restriction or modification, and future sewerage works should be designed with this point held in view.

The density of population varies considerably in the different sections. The best idea regarding it can be obtained from the map published in the *Proceedings of the Engineers' Club*, Vol. II, No. 1, in which I plotted the density from the areas of election divisions, which are comparatively small units, and were the only available data.

The topography of the city varies from very flat and low sections in the southern and eastern parts, to undulating and high grounds, in the west, northwest and north, reaching elevations of several hundred feet. The city is growing chiefly towards the elevated portions, but commer-

* Delaware drainage area, 8,305 square miles; minimum daily discharge, 173,-300,000 cubic feet. Schuylkill drainage area, 1,936 square miles; minimum daily discharge, 30,000,000 cubic feet.

cial interests tend towards gradually covering also the low country towards the mouth of the Schuylkill.

The site of the city, besides being one of the largest built up areas in the world,* is varied in its character from flat to hilly sections, is intersected by several large creeks, viz.: the Wissahickon, Pennypack and Tacony, and includes two large navigable rivers.

The subsoil consists of loam, gravel and clay, varying in depth from 0 to 60 feet, and is underlaid by gneiss-rock. Subsoil water is found only in places, and is slight in quantity, except near the river.

The climate af Philadelphia, respecting the extremes of temperature, their duration and the maximum rain and snow-falls, varies slightly from other towns in the Middle States, but more from most of the large European cities.

Our yearly maximum temperature reaches from 90° to 100°, and our minimum from 10° above to 10° below zero. Our highest temperature is reached within a few degrees, pretty generally in Europe, but the lowest is only found in Germany, Austria and in the countries north and east of them.

The maximum rainfalls that have been registered in our city are found in Appendix No. 2, where also the European storms are tabulated. It will be noticed that the latter are substantially as heavy as our own.

Snow has fallen in Philadelphia to a depth of three feet, and has remained on the ground for several months, the depth of frost being usually from two to three feet. In England and Paris the amount of snow falling is light, as is also the depth of frost, whereas Germany and Austria closely resemble our own city in this respect.

Philadelphia is divided into numerous natural drainage areas. The water-shed line between the two rivers, beginning at Chestnut Hill, traverses Germantown and Nicetown, then passes on to Laurel Hill, from there to a point near Eleventh and Arch streets, and finally loses itself near Point Breeze. The territory towards each river is subdivided into a great number of smaller areas generally running directly to the river.

The natural surface drainage is, therefore, plainly indicated. The artificial drainage by sewers has closely followed it, excepting in a very

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* Area within municipal boundary,	. . . .	129 sq. miles.
" of built up portion of city,	. . .	about 20 "

few instances, such as the short intercepting sewers preventing sewage from entering the Schuylkill River immediately above the dam. In other words, the sewers have, as a rule, been built along valley lines and finally reach the rivers, at or near the points where the rain-water previously entered them.

The surface characteristics are as follows: Streets are paved with Belgian blocks, cobble and rubble stones, and sidewalks are paved with flagstones and bricks, laid on a bed of gravel or sand. Closely built-up sections, which therefore offer little chance for rain-water to soak into the ground, are confined to the older parts of the city The area adjoining them, covered principally with dwelling houses, contains a large amount of garden surface, with lawns or open soil, estimated at one-quarter of the area, on which a considerable portion of rain-water can be absorbed. Further towards the periphery are rural sections, where a still greater amount can soak into the ground. In making provision for leading away the rain-water this circumstance is of importance as determining its quantity and the size of the channels intended to remove it.

The water supply of the city is fair in quantity. It is about sixty gallons per day per head, of total population.* As pipes are laid through the streets of all built-up sections, but not in the village districts, the quantity per head of consumers is even greater.

The existing works for the removal of excreta, waste and rain-water can be briefly described as follows:

There are about 154,000 houses in the city. It is estimated, in the absence of exact statistics, that there are about 75,000 cesspools, most of which are so placed that one serves two houses. It is not far from the truth to say that 145,000 houses have cesspools attached to them. Further, as the sewers have been extended, houses have been connected with them, but the cesspools were not always obliterated, but

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* Water supply of several European cities:

Oxford, *Separate System of Sewerage*,	53 gals. per head.
Paris,	50·2 " "
Hamburg,	46·0 " "
London,	32·7 " "
Liverpool,	32·3 " "
Danzig,	32·0 " "
Berlin,	31·7 " "
Frankfort,	31·0 " "
Vienna,	16·0 " "

left for use and provided with an overflow pipe to the sewer. The number of cesspools thus retained is estimated at one-third, or 25,000. The remaining 50,000 have no connection whatever with sewers, and being lined with a brick wall, usually built without any mortar, and which is perhaps not in a single instance water-tight, allow the liquids to soak away into a stratum of gravel or loam underlying the greatest portion of the city. The serious effects which may result from this in the future are not difficult to conceive.

Records show, further, the existence of about 34,000 water-closets. Some houses have two closets, but they are few. As the average number of persons to a house is 5·5, and among the wealthier classes where the water-closets are generally in use, even less, it is plain that the sewers can regularly receive the excreta from not over 200,000 persons, or less than one-quarter of the city's population.

To this must, however, be added the overflow from cesspools which are connected with sewers. Unless they are water-tight, the overflow will not be regular. Only when a large amount of water, from kitchens or bath-rooms, is suddenly run into them, a discharge into the sewer may take place. The quantity of excreta getting into the sewer this way is impossible to estimate. An idea only may be gained by considering that about 12,000 of the houses, which are connected with the sewers, have cesspools still in use and no water-closets.

These figures indicate that our means for disposal of excreta can be estimated to be less than one-fourth by sewers or water-carriage, and more than three-fourths by cesspools, where the solids are generally stored for months and years and the fluids soak into the soil underlying the city.

House waste-water, where connections are made with sewers, is also led into them from all houses provided with water-closets, therefore from 34,000. In addition, there are about 6,000 houses where only waste water is led into the under-ground drains. And finally, there is a large amount of house-water which runs into the street-gutters and thence into sewers, which has been estimated as equivalent to the entire drainage of 10,000 houses. Therefore, the house-water reaching our sewers may be said to come from about 50,000 houses, representing one-third of the city's population.

Although these figures are rough approximations, yet they are sufficiently accurate to show, as the sewers provide for the excreta of about one-quarter and the house-water of about one-third of the popu-

lation, that water-carriage is by no means the prevailing system in our city, as frequently imagined, for removing faecal matter and liquid filth from our dwellings. It must be added, however, that the yearly increase of water-closets and of connections made with relatively old sewers indicates an increase in their use over cesspools.

The extent of the sewerage executed up to January 1st, 1881, is as follows: Total length of sewers, of which nearly all are circular in shape, is 198·44 miles, costing $4,500,000, of which 44·61 miles are more than three feet in diameter, a few miles only being less. The number of inlets to them at street gutters is about 4500. The number of house connections is about 40,000.

In order now to determine which of the general methods for removing house filth is to be recommended for Philadelphia under the just mentioned conditions it is necessary to review the various methods at present in use and to state the condition under which each one has been found to be best applicable. As I have elsewhere* given a general account of these methods and the conclusions gained regarding their relative merits and applications, I refer to it here and shall only extract as much as concerns my present purpose.

All of the prominent systems for removing waste-water, if properly designed and built, I found to answer the sanitary demands within satisfactory limits. Water-carriage, however, is always preferable to dry methods on account of its greater cleanliness and of the quick and continuous removal of the filth.

Among the water-carriage systems themselves, there is little difference in this respect. The "combined" system, removing sewage and rain-water by the same channels, is preferable to the "separate" system for large areas of thickly populated districts, where under-ground rain-water removal is required, because it is only a single system. This circumstance reduces the number of sewers, facilitates maintenance by allowing better inspection, on account of their greater size, and by the natural flushing of periodical rain-storms. The separate system, however, is preferable to the combined whenever the rain-water can be made to run into old channels or over the surface into the streams, because the fluctuations of the sewage alone will suffer less retention of foul matter than the greater fluctuations due to the admission of rain-water.

*Paper read before the Am. Society of Civil Engineers, June 18th, 1881.

These are the conclusions mainly regarding the sanitary question, and similar ones result when considering the financial question.

A well attended system of dry removal is least expensive, as a rule, only for villages or isolated mansions.

The separate system is naturally cheapest when rain-water can safely and without annoyance flow off on the surface, which is often the case in rural districts, or when it can be turned into old sewers that are not suitable for sewage removal.

The combined system is most economical, as a rule, when storm-water must be carried away under-ground, as from extensive and closely built up districts, and when new sewers must be built for this purpose, which is the case in large or rapidly growing cities.

Local conditions may, of course, modify these points, and in many cases nothing but an examination of the topography and existing works and into the cost itself will determine the most advantageous system.

On the basis of these general conclusions, I shall now state the special conclusions, which I have reached regarding the system or systems best applicable to Philadelphia.

Water-carriage is greatly to be preferred in all districts to which water-supply and sewers can be extended without too great a cost, not only because one-third of our population is already provided for by it, but because the extent of the city, its topography as described, the two large rivers and the abundant use of water, make it the most expedient. The large area of Philadelphia would make a systematic dry-removal enormously expensive, if it is to answer all sanitary requirements. The topography and the soil offer no difficulties in the way of sewerage. The body of tidal-water is sufficient to receive the entire sewage of the city, without creating a nuisance at the wharves, if discharged only during the out-flowing tide. And if, in the distant future, it becomes necessary to purify some of the sewage, there are grounds below the city where a large amount could be used for irrigation. Finally, the abundant supply of water would alone require the use of an extensive sewerage system to remove it from the houses and streets.

The principle of water-carriage, which Philadelphia adopted many years ago in conjunction with other American cities, therefore, is the best one for our conditions.

Yet there are sections of the city where an exception should be made. In the village portions of the county, especially those which are some distance from the city, and which it will be expensive, for many years

hence, to connect with the present sewers, other methods are to be preferred until then, as a temporary expedient. The common privy is not objectionable for country houses, if located far enough from the dwelling and below the stratum from which drinking water is obtained through pumps or springs. A better, because cleaner and more convenient contrivance, is the Dry Earth Closet, which is already much used. For rural districts, a still better method, but more costly and not everywhere applicable, is a separate system of sewerage, for a single house or a small aggregate of houses, with a disposal of the sewage immediately on the grounds, by dispersion into a sandy subsoil.*

As to the particular system of water-carriage which is preferable for our city, my conclusions are as follows:

The magnitude of the several drainage areas, from which a large amount of rain-water will accumulate at the valley lines, makes an under-ground rain-water removal a necessity, especially near their lower ends where the quantity of accumulating water will be greatest, and where, as a rule, the population is most dense, and the greatest amount of traffic is carried on.

The present gradients of many of the streets also make it a necessity, because there are numerous places where a depression is formed at an intersection, giving no possible means for the water to run off, except through under-ground channels. However much this system of establishing grades is to be deprecated, on account of the possibility of flooding the adjoining properties and causing a great fluctuation in the level of subsoil water, and for which reasons it is always carefully avoided in both the large and small cities I visited, it must, nevertheless, be considered in our city, because it exists to no small extent.

The question which now arises is whether the existing sewers can be made to fullfil the sanitary demands in removing the sewage quickly and without deposit, or whether they are only suitable for rain-water. An answer necessitates an examination of various points, which it is more convenient to state later (see Part IV), but I will anticipate the conclusion reached by saying that many of our sewers can be made to fully answer these demands. Yet it may become expedient, near the summit of the drainage areas, instead of rebuilding imperfect ones, to to use them for rain-water alone, and to build new sewers only for sewage.

*Roger Field's Plan.

It therefore appears that a combined system of sewerage is, in general, best adapted to our conditions, but that a partial application of the separate system, on account of the condition of existing works, may become advisable in some few localities.

At the higher parts of the areas extending into the suburbs, where sewers do not yet exist and where the buildings are surrounded by extensive lawns, it may also be more expedient and economical to permanently exclude rainwater from any sewers which, however, only a careful inquiry into each locality can determine. There are large tracts in the north and northwest of the city, where this can undoubtedly be done and a large saving of expense effected.

For some parts of Germantown and Chestnut Hill, from which the rainwater at present runs into the Wissahickon creek, together with the sewage, it will undoubtedly be far preferable to build the sewers for the conveyance of the latter alone and to let the rainwater run over the surface, especially when the roads become properly graded and paved. The smaller sewers can then be more readily united with the other systems, while the rainwater, without the sewage, can alone flow into the creek.

The separation of rainwater from sewage has been advocated also for extensively built-up cities,* but my experience and examinations of the localities where this system is carried out leaves no doubt in my mind that it is impracticable for our entire city. It requires a complete system of sewers for sewage alone and another one for the removal of rainwater. The expense which this duplication would entail upon fo large a city is very great, not to speak of the additional care necessary to properly maintain two systems instead of one.

The towns where separation has been advantageously applied, viz., Oxford, Reading, etc., in England, are small, and in most of them old existing sewers, unfit for the conveyance of sewage were, instead of being obliterated, used as rain-water channels, while new ones, built on modern principles, served for the effectual discharge of sewage. There the expense was less by adopting separation instead of combined removal, but here it would be much greater.

From what has been said it appears finally that the different parts of the city naturally call for different treatment, and instead of applying one and the same system throughout, several systems equally

* Col. G. E. Waring, Jr., recommends it for New York in *Scribner's Monthly*, June, 1881.

good, will, if properly applied, best answer our present demands from an economical as well as sanitary point of view. For the greatest portion of our city the combined system is to be preferred. For rural districts, especially those draining into the Wissahickon creek or Fairmount pool, the separate system will, on closer examination, undoubtedly offer the greatest sanitary as well as economical advantages. Finally, in the distant isolated villages or country-seats within the municipal boundary, so-called dry-removal or private sewerage, with sewage disposal on the premises, is the most acceptable means, financially, of dealing with the problem.

It would now be in place to examine into each of these systems and their details and to trace the direct application to our city. I shall, however, in the following confine myself to sewerage proper, as the most important subject for us, leaving the treatment of isolated, or clusters of, houses, not easily to be reached by city sewers, unconsidered for the present. While the latter is confined in its bearings only to comparatively few, the former influences the public health and comfort at large, and is therefore a more proper subject for municipal action.

I shall also consider the combined and separate systems together, as most of their features are common, and distinguish between them only where necessary.

II. House Sewerage.

The removal of house sewage from the interior and immediate vicinity of dwellings is the most important branch of the system, for it is here where the effects of imperfections become most dangerous to the population. The greatest number of persons spend perhaps twenty hours out of twenty-four in houses. It is their sanitary condition, therefore, which, among external causes, mainly influences the health of a community.

In our city the attention to this subject is entirely in the hands of owners and of such plumbers and mechanics as they choose to engage for new work or repairs. Owners, as a rule, are not conversant with the proper principles according to which their houses should be drained and desire the work to be as economical as possible. Plumbers, on the other hand, are generally guided not by sanitary considerations but, as business men, very naturally, by financial ones. The result cannot be otherwise than detrimental in most cases, and has so

been found and remedied in many cities of Europe and recently in a few cities of our own country, by proper protective regulations.

In the outer sections of the city the common arrangements for a house are: a privy or cesspool at the back, in some cases even in the cellar, and a disposal of the waste water by letting it run over the surface into the gutters of a street. The cesspools or wells are lined with bricks usually laid dry, in order to allow the fluids to soak away into the adjoining soil. This system extends into such parts of the city where no sewers have as yet been built, and to dilate on its evil influences in polluting the soil and air, not to speak of the pump water still used in some of those districts, would be superfluous.

Another method is the underground conveyance of all excreta and waste water into common sewers. Where the latter were built at a later time than the houses the old cesspools, instead of being obliterated, are often retained and used as before, being connected with the sewer by a terra cotta pipe to act as an overflow.

By far the smallest number of houses are drained in a satisfactory manner, and the urgency of effecting a more general adoption of efficient methods is apparent.

Cesspools are being rapidly abolished in most of the European cities. In some they have already practically ceased to exist, as in London, Liverpool, Hamburg and Danzig. In others they are being removed and replaced by either movable casks or pails, as in Paris, numerous German and a few English cities, as Birmingham, Rochdale, Halifax, etc., or they are replaced by the construction or extension of sewerage works. In some cases a prohibitory law already exists with regard to cesspools, in others it is in contemplation as soon as they can be replaced by sewers.

A similar course should be earnestly considered here, as the continued filtration into the soil of the enormous amount of excrementitious liquids cannot but cause the most serious results in future days. Regarding the proper drainage of a house, especially in the details of plumbing, American skill has accomplished as much, if not more, than any city in Europe. In this branch, therefore, we cannot learn very much. Yet in order that not only a few, but the community at large, may benefit from this skill, and that the average house may be as well drained as it is in some cities of Europe, we should adopt a system of public control of house sewerage, to protect the owners from incompetent mechanics or improper work. Providence, R. I.,

has, perhaps, accomplished the most in this respect of all American cities. New York has recently made a successful move in the same direction, and it is to be hoped that other cities will soon follow. Regulations such as are adopted in the cities of Frankfort, Hamburg, Berlin and by the Seven Oaks Local Board, England, are attached to this report.

The most systematic regulation appears to be in Frankfort; although connecting with sewers is not made compulsory. Whoever desires to make use of them must submit plans of the entire drainage in his house for examination and approval, and the works are then carried out under municipal supervision. The result is an efficient design and good execution. In our city, on the other hand, sewer connections are compulsory under certain conditions, and the works are carried out under no supervision, and sometimes even against the desire of the owner. The result, in the majority of cases, naturally is inefficient design and bad execution.

It is evident that in this direction good legislation is much needed and should be urged. In all cities where it has been exercised great benefits have accrued. Our water and gas pipes are already subject to it for financial reasons only, and the sewer pipes should be added for sanitary reasons.

I shall not dilate on the details of house sewerage, but only indicate certain features which have a direct bearing upon the street sewers.

The sizes of the pipes need some consideration. To make them larger than is necessary is an evil, because the relation between frictional surface and bulk is increased, the stream is made shallower and deposits its suspended particles. To give proofs of this would at this day be almost superfluous. I will only mention a most striking example, shown to me in a large private mansion in London. The first sewers were about three feet in diameter, and had become gradually filled within a few inches of the top by reeking filth, while the present sewers, put in their place, were 6 and 8 inches in diameter. These have carried all the sewage, and after years have not shown the slightest deposit nor emitted any objectionable odor. The principle has been amply tested in many localities for a long time. Lately, Col. Waring has recommended a maximum diameter of 4 in. for house pipes in Memphis. When I state the fact that the dry-weather flow

*See Appendix No. 3.

in our Mill creek sewer, which is 20 feet in diameter, and drains an area of over 3000 acres, could run through a 10-in. pipe, the absurdity of using this same size for a single house becomes apparent, and the effects cannot be other than to cause deposits in the pipes. Our plumbers usually put in 8-in. pipes, often 10-in. and sometimes 12-in. There are instances here where even 18-in. and 20-in. pipes were laid to drain a single house, and the consequences cannot be dissimilar to those in the London mansion just mentioned.

If street sewers are not to be obnoxious, the house sewage must be delivered into them while it is fresh. When they receive liquids and solids that have already become foul in the houses, the escape of deleterious gases is difficult to prevent. Smaller sizes, certainly no larger than 6-in., properly planned and laid, would therefore aid in improving not only the condition of the private sewers, but also that of the public sewers.

Another point can directly effect the street sewers, namely, that of the ventilation of house pipes. Without entering further upon this subject here, I will only state, that one of the most efficient methods, tested by long experience, is that of ventilating street sewers partially through the soil pipes of houses. It is done in the best drained continental cities, as Berlin, Hamburg, Frankfort, Danzig and others, lately also in Memphis, Tenn., and promises to be, at least for small sewers, a very satisfactory way of assisting the exchange of air. The soil pipe is carried above the roof, and the main trap, usually inserted where the sewer leaves the premises, is omitted, which gives a free passage for the sewer air. Injurious effects cannot be caused hereby, as the gases created in house pipes are, as a rule, more obnoxious than those forming in street sewers, and if the former prevent an improper escape of their own gases they will also prevent an escape of the others. To use rain-water pipes for ventilation is improper, not only because they hinder the escape of air at times of rain, just when it is required by sewers filling up and expelling it, but because they are not as tightly joined as soil pipes, and may effect the air entering the garret or other windows.

Ventilating sewers through the soil pipes of private houses are also specially beneficial for the latter, because they provide for a constant circulation, which could not be otherwise obtained, except by a special opening to the air in their lower part, which is not always acceptable.

The gain which this aid to the ventilation of the entire street system produces is sufficiently great to demand at least serious consideration. The value of puplic control here, too, becomes apparent, because a single property owner is not interested in ventilating the street sewers nor would ventilation through soil pipes be very efficacious, unless the system were adopted in all houses.

It must finally be stated, what differences will be required in the arrangement of house drainage, when the general system is a combined or a separate one. For the latter, no rain-water should be admitted into the sewers receiving the house-water, unless a small portion is deemed expedient for flushing purposes. For such localities in the suburbs of our city, where the separation would be appropriate, special rain-water sewers would hardly be required on account of their rural character, and the water could run over the surface as heretofore. If, however, expense is not an obstacle, special drains, if desirable, can still be laid in such localities on private ground, but then discharge the rain-water into the gutters of the street.

(To be continued.)

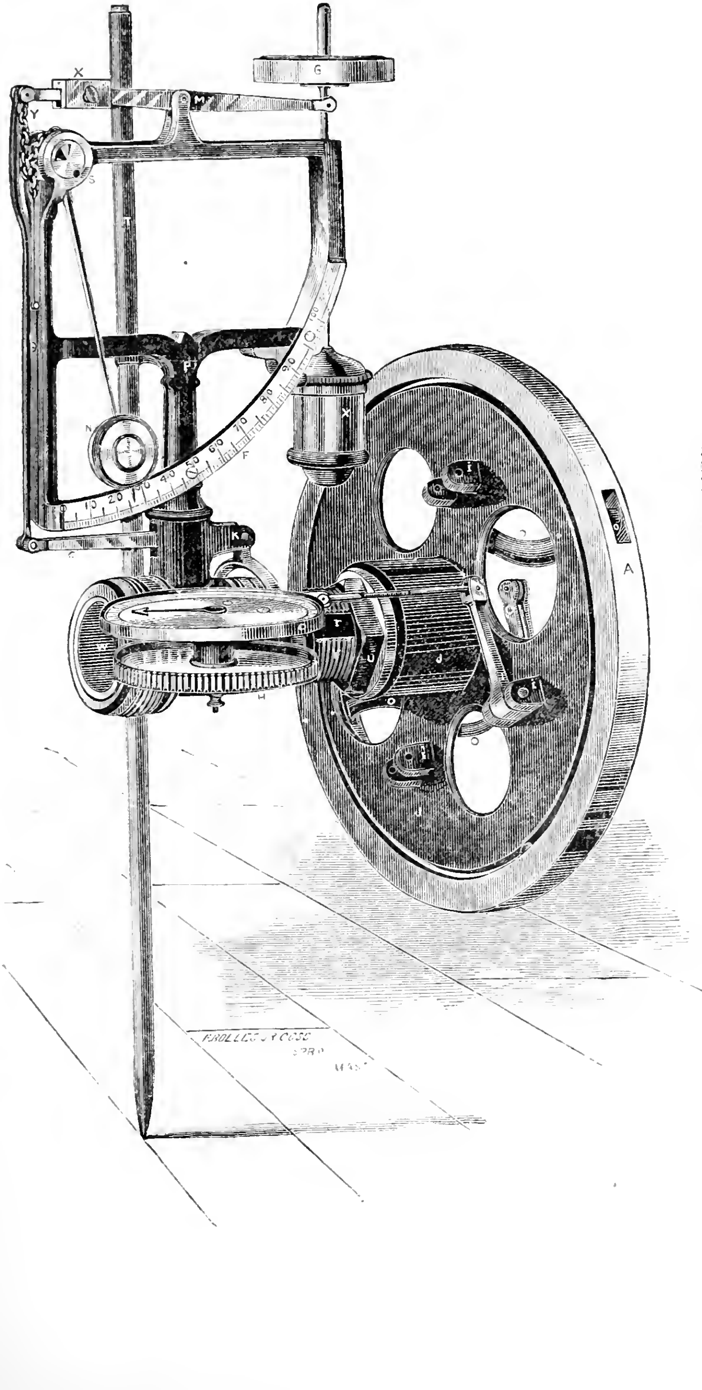
Electric Light by Water Power.—Sir Robert Kane estimates the water power in Ireland as equivalent to at least one and a quarter millions horse-power. He recommends the adoption of Grierson's plan for utilizing the power, by means of electrodynamic machines. When the cost of the machines has once been paid the running expenditure will be trifling. The system has already been tested in the village of Godalming, which is traversed by the Wey, where the power of the river has been successfully applied to the illumination of the streets by electric light. It would be easy to repeat the experiment in some other village of greater importance, and there is no doubt that the result would be equally favorable. Dublin, for example, surrounded by two fine canals, and traversed by the Liffey, is admirably situated for conclusive and economical experiments. The adoption of Grierson's project would undoubtedly be very advantageous for Ireland. It could also be applied in Paris, where the utilization of the Seine ought to be tried. Our electricians who have already illuminated certain portions of the capital would render an immense service to the citizens by giving them an illumination which is more certain and more economical than gas.—*Les Mondes*, xxxi, 546. C.

EMERSON'S POWER SCALES, OR DYNAMOMETER.

By Jesse H. Lord.

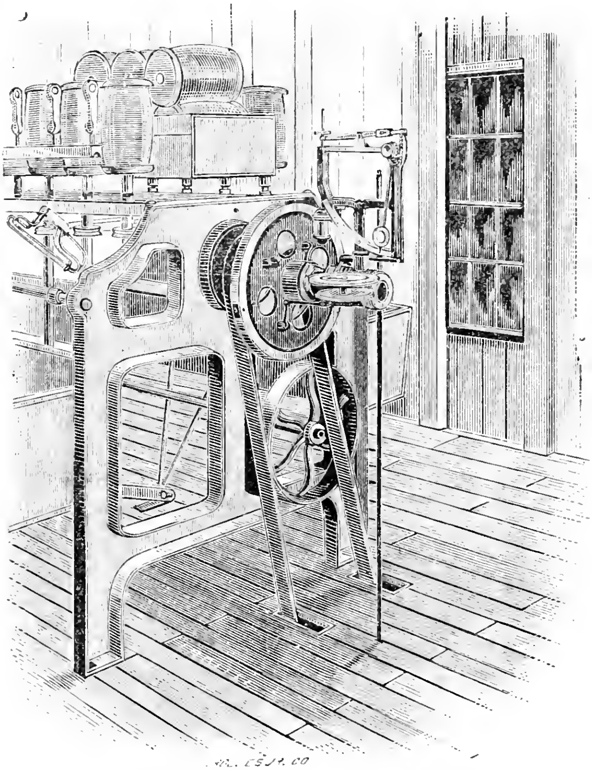
A number of attempts have been made to construct a power measurer which should give absolute results in foot-pounds; but most of them had some inherent defect, either in construction or application. Some have depended upon springs for efficiency, others have been intended for fixtures; most of them gave only relative results, and none of them were simple, portable, easily applied attachments. So many mechanics insist on a resort to the Prony brake as preferable to any and all so-called improvements. Yet a good dynamometer is unquestionably to be desired, as a useful implement to the manufacturer, millwright, the leasor, and to the hirer of power. James Emerson, of Willimansett, Mass., has perfected a power scale that appears to possess all the requisites desired. Unlike most other power measurers, this demands no change in the machine or shaft to which it is applied, beyond the removal of one of the pulleys, if a tight and loose pulley are used, the pulley-arms serving as means of propulsion or actuation of the power measurer. No springs are used on the machine, and all the movements are direct and absolute. No comparison with some other standard is required, as this machine gives absolute results instead of relative indications. It short, it is a power scales, and really weighs the "strain," "resistance," "friction," or "inertia," just as truly as the Fairbanks scales weighs the gravity of a load; and, like the Fairbanks scales, this may be considered a standard. The elements of its operation are speed of the machine, to be weighed or measured in feet, and resistance of the machine in avoirdupois pounds. Both these data are given by the appliance at the same time, and both are represented in plain figures. The result of the two multiplied together is the number of foot-pounds, which may be easily reduced to horse-power or its fractions if this is desired.

The larger engraving represents the power scale detached, and the smaller engraving shows it attached to a machine from which the loose pulley has been removed, and the tight pulley is made a loose pulley by having its set-screw slacked up or its key removed. The utility of this remaining pulley is to receive the driving belt, that the machine to be tested may be run at its normal speed.



EMERSON'S DYNAMOMETER.

The power scales has a disc of 12 inches diameter, to which, and its hub, all the attachments are made. It is secured to the end of the shaft of the machine to be tested by means of a split threaded sleeve with wedge-shaped jaws, formed to fit shafts from $\frac{7}{8}$ of an inch diameter to $1\frac{5}{8}$ inches diameter, and the adjustment requires but two or three minutes of the time of an intelligent workman. In fact, the adjustment of the power scales is similar to that of an object to be bored in the jaws of a lathe chuck.



In the larger cut some of the letters of reference may be of use; the levers O are pivoted at A in the disc, and connect with the arms of the driving pulley, or if the pulley has a solid web, with the sides of holes drilled through the webbing. The object is simply to give a rotary and "bearing" motion and resistance to the levers, which by bell cranks connect with an annular collar on the power scales, so as to actuate the lever C by the yoke K, that gives movement to the pen-

dulum N. This connection between the rotating movement of the shaft of the machine to be tested, and the reciprocating motions of the pendulum and the lever C, is similar to that of the old-fashioned throttle governor of the steam engine, and can be readily understood by all mechanics.

The marking scale beam of this power measurer is exactly like that of the Fairbanks' scale in principle, being modified only by having a pendulum instead of a *pois*, and being a quadrant instead of a straight line. The letter shows how adjustment for perfect balancing can be made; G shows how weights may be added to increase the capacity of the power scales, this 12 inch size being capable, at 1,000 revolutions per minute, of weighing up to 25 horse-power, other speeds proportionally, and the letters W and H show the method by worm and gear of getting the number of revolutions of the machine to be tested. A staff, T, or a pointed bar, is used to rest on the floor to prevent the friction of the shaft from moving the pendulum and scale out of a perpendicular, and the dash-pot X combines with the adjuster-block X to prevent undue oscillation of the pendulum.

The total weight of this size apparatus is so slight that it may be carried easily under the arm, and its readiness for use is such that ten minutes is amply sufficient to apply and adjust it. No previous schooling or drill is required to enable an overseer or boss to apply this power scales, as is necessary in indicating a steam engine; and yet this apparatus is intended to do for the manufacturer, and for the hirer and the letter of power what the indicator does for the proprietor of steam-power,—give the facts about the amount of power used and its cost; and this it does with accuracy.

Use of Phosphor-Bronze for Electric Transmission.—The successful experiments with phosphor-bronze for telegraphic wires have led to various speculations with regard to an extension of its employment for other electrical purposes. When the transmission of force to a distance by electricity comes extensively into use, wires will not only be required for its conveyance, but there will also be a need of dynamo-electric machines rotating at immense speed. It will then be important to have bearings which heat but slowly, and which are not readily worn by friction. These qualities are possessed by phosphor-bronze in an eminent degree.—*L'Electricien.* C.

MECHANICAL MODIFICATIONS OF THE BESSEMER PLANT NECESSARY TO ADAPT IT TO THE ECONOMICAL WORKING OF THE BASIC PROCESS.

By WILLIAM M. HENDERSON, M.E.

The most difficult problem which has presented itself in the solution of the basic process is undoubtedly the vulnerable character of the refractory lining of the converter. The importance of having some prompt, unlaborious way of renewing the linings will be best understood by referring to the fact that while a converter for conducting the ordinary Bessemer process requires renewal about every three months, a converter for the basic process requires renewal about every sixty hours, and as the relining of such a converter occupies from fifteen to twenty hours, the quicker it is effected the better for the output and the cheaper for the product.

Of the methods which have been proposed, one is to double the entire converting plant, and do all the repairs to the converters and reline them where they stand; but this is obviously very costly, both as regards outlay and waste of room; it is besides exceedingly inconvenient. The primary object of the converting department being to produce ingots, is not the place to repair refractory linings. Whenever a vessel is unfit for steel making it should be removed at once out of the way and replaced by another ready to continue the work, in the same way as the ladles and vessel bottoms are at present handled. The same may be said of stripping the ingots after the moulds are filled. They should be taken out of the converting department at once to a stripping room furnished with suitable cranes and other hydraulic appliances specially arranged for the purpose, doing away with all the confusion now existing and brought about by stripping the ingots in the pits in front of the converters, seriously interfering with the business of making steel, a matter which should be separated completely from the work of repairs, etc.

Another plan proposed is to replace each entire converter by lifting it bodily out of its trunnion bearings by a powerful overhead traveling crane and conveying it away to the repair shop, and bringing another in working condition by the same means to take its place.

It is apparent this must be an exceedingly slow and tedious operation. First removing the heavy nuts from the pillow block caps, then the caps themselves, and then bringing the carriage of the traveling crane directly over the converter so as to lift it squarely out of its bearings, and making fast a chain capable of lifting thirty tons; the time consumed in taking it away, depositing it, casting loose and repeating, in an inverse manner, all these operations with the repaired one will not show very favorably for this method. I am informed this arrangement is in actual use in Europe and has been patented in this country.

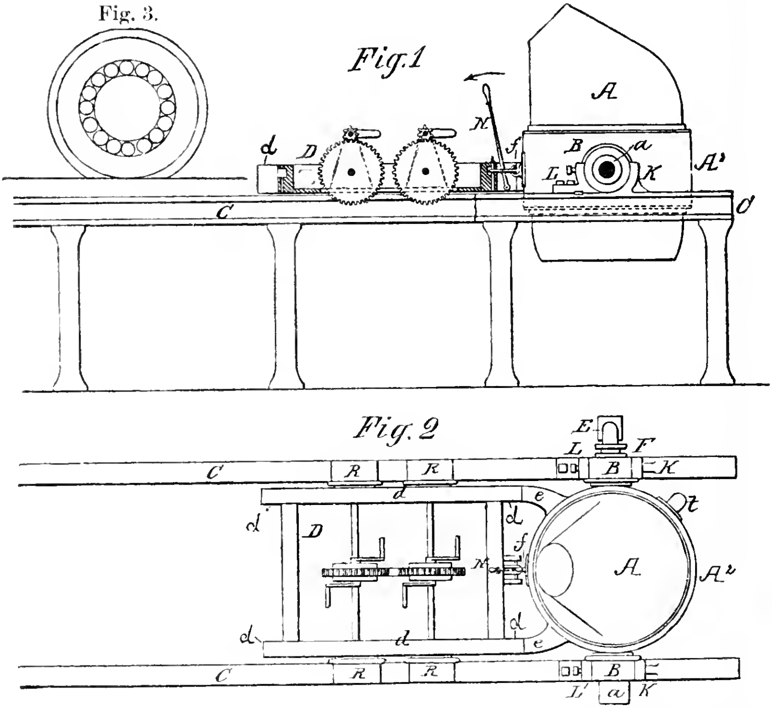
We now pass to the method proposed by the late Alexander L. Holley, which consists in removing the shell of the converter (the wrought iron egg-shaped vessel containing the refractory lining) by lowering it out of the trunnion ring. When it is desired to replace a worn-out lining, the shell is cast loose from the cast iron ring or belt which carries the trunnions, by knocking out about a dozen keys from the 2½-inch vertical bolts, which bind the shell to the ring; the converter is first turned nose down, and a powerful hydraulic lift, situated immediately under the centre of the converter is raised to receive the shell, which is then lowered out of its ring until it rests on end upon a four-wheeled truck running on a railway beneath; in this condition the shell is conveyed to the repair shop and replaced by another by the same means, each shell having an individual truck provided for its use. It was found that this arrangement required the converter to be hung about 20 feet above the general ground level in order to give room to lower the shell out of the trunnion ring and to remove it laterally, requiring a second hydraulic crane and ladle in order to get the charge down to the working level.

To obviate this difficulty Mr. Holley took out a subsequent patent for removing the pillow block caps, disconnecting the shell as before, and hoisting the entire trunnion ring, by tackle, clear over the top of the converter, so that the shell could be removed laterally without being lowered. Here we fall back again, encountering some of the objections found in plan number two, and it must be admitted dismantling a red-hot converter where it stands is not a commendable feature.

Such is the history of the appliances devised for removing the linings of converters adapted to the basic process, up to the time the

writer obtained a patent for the same purpose, which will now be briefly described.

Fig. 3.



Figs. 1 and 2 of the accompanying engravings show a side elevation and plan of this improvement, in which *A* is the converter, substantially the same as other converters. The improvement consists in turning the ordinary pillow blocks, in which the converter trunnions revolve, into flanged wheels, *BB*, by means of which the converter may be run in and out of working position for use and for repairs, the track consisting of the girders, *CC*, usually provided, and they may be arranged to communicate with such sidings or turnouts as may be found necessary to provide room in the repair shop for their reception. When the converter is in working position the flange wheels are confined between fixed stops, *KK*, on the girder, and removable chocks, *LL*, secured by keys and bolts as shown; the wheels, thus secured, become to all intents and purposes pillow blocks, as before, in which the trunnions can revolve when the converter has to be tilted; this tilting of the converter is accomplished by the usual

rack and pinion motion, operated by a hydraulic cylinder not shown on these cuts.

The power truck, *D*, for traversing the converters, is provided with two axles, each having a pair of flanged wheels, *RR*, which follow the same track as that provided for the converter; a spur wheel, keyed on each axle, gears into a pinion on a shaft carried by suitable frames secured on the truck, provided at each end with a crank handle. The side beams, *dd*, of the truck, project from each end of the same, and are arranged to abut against projections, *ee*, on the converter, a hook, *f*, on the latter being adapted for coupling by a link to a pin in the truck, a rigid connection being effected by means of the lever, *N*, which is pivoted to the truck. Thus by forcing the lever in the direction of the arrow the truck must be made to bear hard against the projections, *ee*, before the coupling pin can drop into its place. When the truck is thus coupled to the converter it forms with it a vehicle which may readily be wheeled away.

The diameter of the converter wheels to suit the present height of trunnions above the girders would be about 30 inches. The diameter of the tram wheels may be the same, and the same diameter will answer for the gear wheels. Driving pinion $5\frac{7}{8}$ diameter, 12 teeth; diameter of gear wheels 30 inches, 63 teeth, $1\frac{1}{2}$ pitch, $3\frac{1}{2}$ face; proportion of gearing 5 to 1; leverage of crank over pinion 5·44. With two men stationed at the cranks, each exerting 18 pounds against the handles, we have 18 lbs. $\times$ 5·44 = in round numbers, 100 lbs. $\times$ 5 (proportion of gearing) = 500 lbs. $\times$ 2 men = 1000 lbs. If the initial resistance to be overcome to start the load is taken at the fair allowance of, say, 20 lbs. per ton, the force here expended would be equivalent to moving a converter weighing 50 tons, and as the converter would weigh, empty of metal, and with the bottom removed, about 30 tons, a fair margin is left for those obstacles in the way which no amount of calculation can provide for. At 16 revolutions of handle, the car conveying the converter would travel 24 feet 6 inches in one minute. By arranging friction rollers between the journals of the trunnions and their bearings, as in Fig. 3 the friction may be very greatly reduced. The friction of trunnion journals in their bearings being a species of sliding friction, following a circular path instead of a plane, the coefficient is slightly different, but sufficiently analogous that the following experiment may be accepted as a fair exponent of what would follow by the use of friction rollers.

I took two smooth planed surfaces, wiped clean with oily waste, the upper weighing 363 lbs., to which was attached a cord leading over a pulley; it took a weight of 62 lbs. on the end of the cord to move the plate by sliding, about $\frac{1}{6}$ of the weight. I then placed fourteen one-inch smooth rollers $7\frac{1}{2}$ inches long in contact with each other, similar to the sketch, under each end; the plate was then moved by $3\frac{1}{2}$ lbs., the 100th part about of the load, and by comparison, about the $\frac{1}{18}$ part of what was required for sliding.

The effect of friction rollers in lessening the friction of the trunnions of a converter in their bearings is of such a marked character that I would strongly recommend their use even to existing converters; the ponderous hydraulic cylinder now necessary to revolve the converter could be replaced by one of much smaller dimensions. From this it will be seen that by the use of friction rollers the force required to transport a converter may be greatly reduced, and by their use it is plain the very largest converter possible to be made or used could be handled with ease.

The more prominent advantages claimed for this method of renewing the linings of converters for the basic process over the removable shell system are as follows:

1. It dispenses with the necessity of having the converter raised to the impracticable height of about 20 feet above the general ground level.

2. It dispenses with the necessity of having a special hydraulic lift, extra powerful and long stroke, for raising and lowering the shells.

3. It dispenses with the necessity of having an intermediate ladle and crane between the converter and the ingot ladle to get the charge down to the working level.

4. It removes the converter track completely away from the debris and great accumulation of slag thrown off by the basic process and the refuse dumped below at the end of each heat.

5. It provides room underneath the converter for the introduction of the gas main, and pipes to rapidly dry the converters after relining.

6. The converter being made to connect again with a hydraulic cylinder and rack in the repair shop, is as manageable undergoing relining and repairs as when working. It can be turned round to any desired position, greatly facilitating relining and repairs.

7. Another advantage is the ease and rapidity with which a converter can be set free for removal, and replaced by another in working

condition, by the simple removal of two chocks, which lock the wheels in working position, reducing the labor to be done in the coverting department on a red hot vessel to the minimum.

Steelton, June 10, 1882.

ON THE PREVENTION OF FIRES IN THEATRES.

By C. John Hexamer.

[A paper read at the Stated Meeting of the Franklin Institute, held June 21, 1882.]

(Concluded from page 134.)

But plugs should not be solely relied upon for protection in theatres, from the fact that their usefulness depends entirely upon the courage of the employés. It is too much to ask a man to stand and fight fire when he knows that there is a tinder-box between himself and safety, and that at any moment a drifting spark may cut off his only chance of escape. Sometimes such heroes do exist, who pay for their bravery with their lives, but these are only warning examples to others not to risk their own in similar efforts.

In this case we must again take our resort to automatic means, and for this purpose automatic sprinklers, which have been in use in mills for some time, would be of great value.

As a plentiful supply of water is not always at hand, and as steam-pumps frequently get out of order, large reservoirs should be placed on top of theatres. These should be placed on top of the auditorium and not in the rigging-loft The stage, as the most inflammable part, being generally ignited first, would (if the reservoirs were placed on it) deprive the remainder of the building of water.

In order to keep the water in these tanks from freezing, the exhaust-steam pipe of the engine should be made to pass through it; or, as this is not always convenient, it should be mixed with salt (salt water having a lower freezing-point than pure water). The addition of salt would also have the wholesome effect of preventing the formation of algæ (the green slime found on ponds and other still water), which are obnoxious by their smell and by the tendency they have of closing the pipes.

Every theatre should have a fire brigade consisting of at least five

men; these should be present at all performances, and should be perfectly familiar with the theatre and all its fire appliances.

At Carlsruhe (the seat of the famous polytechnic school) the authorities, after the great fire of the "Hoftheater," organized a fire patrol of students. These are stationed all over the theatre, know all appliances, and, as a corps of gentlemen, must be much superior to ignorant men, both in case of fire and in quieting a panic.

Watchmen should be constantly on the premises, and, to control them, watch-clocks should be fixed in different parts of the building.

Automatic fire-alarms, placed in various parts of the stage, would be of great use, as the fire department is generally notified too late.

We now arrive at the most important question: *The safety of audiences.*

From the numerous accounts of theatre fires which the author has collected he finds that loss of life is caused by (1), suffocation by smoke; and (2), the crushing and trampling of the panic-stricken masses.

Experience shows that death is mostly caused by suffocation, and that the burning of bodies is a subsequent occurrence, taking place after life has already become extinct. This was again clearly illustrated by the late Vienna fire, as will be seen from the following account of a civil engineer, given at the time, in several Vienna papers:

"This gentleman, with his wife, was sitting in the second gallery, and, fortunately for himself, was one of the first to discover the fire; they quickly got up and walked out, while the majority of the audience had no idea of the occurrence. The lights were burning until they reached the last steps of the second story, when all lights were suddenly extinguished. While they were still in doubt in what direction to go, they were carried, by a sudden rush, to the right, and found themselves in front of a glass door. This door was broken open, when they saw that they were, with some twenty-five other persons, on the balcony fronting on the '*Hessgasse*' (Hess Street).

"The gentleman, seeing his wife safe, returned to the corridor and loudly shouted: 'This way for safety!' He received no answer. He then went further, until checked by the smoke, but already, at this short distance, saw several corpses. Thereupon he went back to the balcony and saved himself by jumping on the cloths in the street."

He concludes from this that after this short time, already, every one in that gallery was suffocated. Although we cannot tell how long it took to suffocate all these people, we can safely state that they were

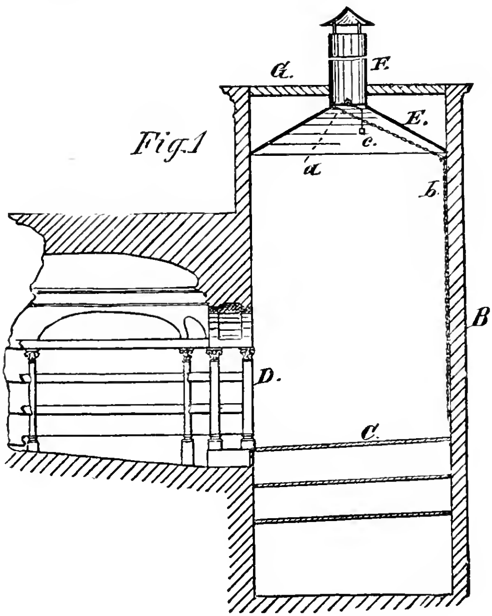
suffocated and not burned to death, the bodies having been burnt later.

We must, therefore, get rid of the smoke in the quickest and best manner possible. This question has been solved by the ingenious device of Hofman, which acts in conjunction with his automatic drop curtain, and by Mr. Louis Sues of Chicago.

The intense smoke in the auditorium, during a fire on the stage, is caused by a draft of hot air from all parts of the house towards the open doors and ventilator.

The latter is usually situated above the main chandelier in the centre of the auditorium ceiling. This draft may frequently be noticed by the sail-like outward bulging of curtains.

Fig. 1



We must, therefore, form a counter draft which, in case of fire, would be strong enough to overcome the combined action of the doors and ventilator.

This could best be accomplished by a chimney or flue on the top of the stage which would take off all smoke and cinders. Or, as before stated, *making a perfect shaving vault of the stage.*

We will now describe the different solutions advanced for this problem, beginning with the simplest.

A good idea was suggested a short time ago by one of the inspecting chiefs of the New York fire department. It was, to make the roof over the stage a vast skylight, the glass of which could be broken in case of fire and a draft thus created which would carry the flames upwards and prevent them spreading to the auditorium.

Next in order comes Mr. Sues' smoke flue, the description of which I quote from his patent specification. Fig. 1 is a vertical section. Fig. 2 is a detail in perspective.

"Theatres frequently take fire and in almost all cases the fire originates in that portion of the building devoted to the stage and scenery. There is usually a draft from the stage to the auditorium, especially when the doors are opened and the flames and smoke pass rapidly from the stage to the audience-room."

"The object of my inventions is to construct theatres so that this difficulty will be obviated to a great extent, and it consists in a large outlet in the roof over the stage for the passage of smoke in case of fire, so that a current of air will be induced from the auditorium to the stage instead of from the stage to the auditorium, and combining with such outlet a ceiling over the stage portion of the building which will for a considerable time resist the action of fire, thus giving the audience time to escape.

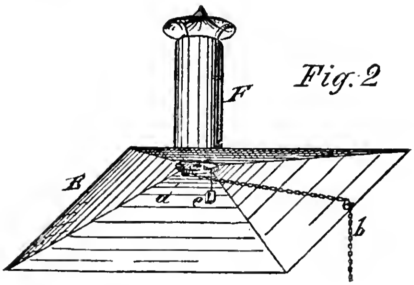


Fig. 2

"In the drawings, *A* indicates the auditorium; *B* that portion of the building devoted to the stage; *C*, the stage; *D*, opening between the stage and the auditorium; *E* is the ceiling over the stage. This ceiling I make practically fire-proof, either by making it wholly of metal or by the use of metal joists with wire or wire-cloth for lathing, and usual plastering, or in other suitable manner. *F* is a large passage to be made of fire-proof material. It passes through the roof *G*. Its lower end is properly secured in the ceiling and is open, except when closed by the valve *a*. *b* is a chain by means of which the valve *a*

can be opened. *c* is a weight which holds the valve in position when closed.

"The operation is as follows: If a fire breaks out upon the stage the valve *a* is to be immediately opened. The ascending heat and smoke will rise to the ceiling and escape through *F*, thereby producing a current from the auditorium to the stage, instead of the reverse, thus keeping the smoke and flames from the audience-room while the audience is escaping. In cases where a fire-proof drop-curtain is used suitable openings may be somewhere provided to admit air to the stage.

"In theatres of the usual size the passage *F* should be about six feet in diameter. It may be carried some distance above the roof which will increase the draft.

"Two or more of these passages *F* may be used. The opening at the top of the passage *F* may be protected from storms by caps."

This is an excellent device, the only objection to it is that it is not automatic; its usefulness, in case of fire being, therefore, dependent on the coolness of the men having it in charge.

The ingenious device of Hofman combines an automatic wire drop-curtain, and automatic smoke flue and an automatic fire alarm. This device will act without the aid of a single hand, being entirely automatic.

It consists of a safety-rope, which runs on pulleys over the principal and most dangerous parts of the stage. This rope is prepared so as to be the most combustible substance on the stage. In case of fire, it will, therefore, ignite and burn off almost instantly. Has this moment arrived, a heavy weight, held by the safety-rope, falls. This weight being connected with the machinery of the curtain by a lever, the lever is raised, the machinery set in motion, and the curtain lowered. Not, however, with a sudden fall which might damage it, but steadily.

The falling of the heavy weight, at the same time, opens the valve of the large smoke flue contained in the roof of the stage, whereby the smoke and heat of the fire is kept on the stage and taken out of the flue; thus giving the audience time to leave the theatre quietly and orderly, without being threatened by smoke or heat. The same moment the above takes place the fall of the weight sets a fire alarm in motion and the fire department is notified.

We have now seen the different devices for getting rid of that greatest danger to audiences—smoke—and can now compare their

relative values. The first would be very simple, but in the time required for the firemen to arrive and break in the glass of the sky-light, the audience might be suffocated.

The second is an excellent patent, its only objection being, as before stated, its want of automatism.

The third, to the author, seems undoubtedly the best, for if in case of fire, the men having it in charge should neglect to open the valve, it would act automatically; not to speak of the immense value of the automatic wire drop-curtain and fire-alarm.

The writer has frequently noticed the time required by audiences to vacate theatres, and out of numerous experiments finds it takes from $3\frac{1}{2}$ to 11 minutes for a theatre to be entirely emptied. But this time is protracted indefinitely in case of a panic. It has been found that in cases where audiences had ample time to vacate theatres many were killed, although not prevented from escaping by the smoke.

This is explained by the jamming of crowds in corridors. A mass of people may best be compared with a number of logs floating down a stream, which at some point, by their mutual pressure, form arches across it, thus becoming wedged fast. In the same manner persons form arches across corridors which are sometimes broken, only to be formed again.

This, the cause of many deaths, may be remedied by making the walls of corridors inclined towards each other, being narrowest in the theatre and widening towards the exit doors, as it is impossible for logs to jam in a widening water-course.

There should be outlets from each gallery or floor separate and distinct from every other outlet, so that a crowd from one gallery cannot precipitate itself upon a crowd from another floor that is struggling to get out.

A matter still sometimes neglected is, that all doors should open outwards, the people of the fourth gallery at the recent Vienna fire, for example, were hindered from flight by the doors opening inwards.

Most theatres have a sufficient number of exits, but in order to save doorkeepers most of them are locked; some not being satisfied with locking them, even nail and bolt them shut.

Corridors are also frequently too narrow; these should never be less than eight feet broad, which would allow, at most, but five persons abreast.

Another outrage to humanity are high galleries. In American

theatres there are never more than three, but in Europe they have as many as five.

Law should forbid the erection of more than two galleries, *i. e.*, a "balcony" and "family circle."

The horrors of theatre fires are always increased by the total darkness which envelopes audiences a short time after commencement of the fire.

This is frequently caused by the explosion of gas on the stage. To obviate this, all theatres should separate the system of lighting the auditorium from that of lighting the stage.

After years of hard work, the authorities of Vienna succeeded in compelling managers to have oil lamps in corridors. The order was complied with, but, as was seen by the late catastrophe, these were never lighted.

It has frequently been urged, especially by "insurance men," that the risk from fire would only be increased by the use of coal oil in these lamps. But it is not necessarily said that petroleum must be used, for any of the heavy oils (used long before coal oil was known) might be employed with advantage.

If these should be objected to, let it be remembered that festivals which outrival everything in history by their splendor, and that the plays of a Corneille and a Moliere were first produced before the eyes of the then most powerful king of Europe, by the light of *candles.* Why should these then not satisfy us in the humble position of safety corridor lights?

Particular attention should be paid to the calamity at Carlsruhe in 1847. By the inattention of one of the servants in lighting the gas the drapings of the Grand Ducal box caught fire. All parts of the house were crowded, over 2000 persons being present. The flames instantly spread to the balcony; every one tried to escape in the greatest hurry. The audience of the parquet, as well as that of the balcony, saved themselves, but the greatest confusion ensued in the higher galleries which were in a short time filled with smoke.

Of the four exits, but the one under which the fire broke out was open. Every one rushed to this exit and very soon it was jammed shut. The scenes following were indescribable: A few climbed or jumped from the galleries; others threw themselves out of the windows; many were crushed to death, and most were suffocated by the hot smoke.

In the narrow corridors people were lying in heaps. To this was added that immediately after the breaking out of the fire the gas was turned off from the street and the building thrown into total darkness. The situation of the people, jammed fast in corridors, without light, enveloped in smoke, was frightful.

This catastrophe cost the lives of sixty-three persons, and over two hundred were terribly wounded.

As before mentioned, the theatre had four exits, but to save the expense of extra doorkeepers three of these had been closed for years, and not only locked, but nailed and boarded shut, and but few knew the existence of these extra exits.

One cause saved the lives of many—gas had not long ago been introduced and on this account many oil lamps had been retained to do duty in corridors. These lamps, which had been the objects of wit and sarcasm, saved the lives of hundreds.

We had at Vienna the counterpart of Carlsruhe, only in this case the lamps were not lighted or hundreds of unfortunate victims would have been saved.

It can, from this, be seen how necessary oil lamps are and that in the deciding moment this precaution will save many lives.

Before concluding my remarks it may be well for me to give an example of a theatre, which was managed in the correct manner, which had many of the modern improvements, and which at the same time is the first case on record in which *the entire* audience of a burning theatre escaped in safety. On the 16th of April, of this year, during a performance of the farce "Robert and Bertram," at the "Hof-Theater" of Schwerin, the cry of fire was suddenly heard from one of the galleries. As no flames or smoke were perceived the audience remained seated, until the news came from the outside that the roof was burning. The Grand Duke, who was present immediately addressed a few words to the audience and ordered the musicians to continue. The stage-manager also assured the audience that there was no danger. But soon the wire curtain had to be lowered, and now the audience left the theatre in the greatest order, especially the densely packed galleries were rapidly cleared, the audience escaping through the numerous exits, *which were all open.* For some time previous to the occurence audiences had been instructed—by means of large placards hung up in the corridors—how to act in case of fire. The *oil-lamps were all lighted*, and the wire-curtain was in *good working order*,

thus for the first time, practically illustrating its use. On account of these excellent arrangements it was possible for the whole audience to save itself, although many ladies and children were present. Here we then have an example to show how, with proper precautions, faithful employés—especially the man who let down the wire-curtain—and cool, collected conduct, an audience may be spared the dangers of a theatre-fire. The beautiful theatre burned down, also the large Concert Hall attached to it. But the only life lost in the event was that of a fireman who was buried under a falling wall, this occurring a considerable time after the audience had escaped.

The author hopes to have shown how theatres can be built, although not fire-proof, yet in a manner so as to give safety to audiences.

Theatres *could* and *should* be built so that the largest audiences could escape in safety.

THE CHEMISTRY OF THE PLANTÉ AND FAURE ACCUMULATORS.

By J. H. Gladstone and Alfred Tribe.

Part I.—Local Action.

Among the important discoveries of late years few have claimed so much attention, or have been so full of promise for practical use, as the accumulator of Planté and its modifications. Our attention was very naturally directed to the chemical changes that take place in these batteries, especially as it appeared to us that there must be certain analogies between them and some actions which we had previously investigated. In the present communication we propose to treat merely of one point—that of local action, leaving the fuller discussion of the subject to some future occasion.

It is well known that metallic zinc will not decompose water even at 100°C., but we found that zinc, on which copper had been deposited in a spongy condition, was capable of splitting up the molecule even at the ordinary temperature, oxide of zinc being formed and hydrogen liberated. If placed in dilute sulphuric acid it started a very violent chemical action, sulphate of zinc and hydrogen gas being the result. We termed the two metals thus conjoined, the *copper-zinc couple*, and this agent was fruitful in our hands in bringing about other chemical

changes which neither metal singly would effect. Electricians will readily understand the nature of this agent, and will recognize in its effects only a magnified form of what we are all familiar with under the name of *local action.* Now the negative plate of a Planté secondary battery is a sheet of lead, upon which finely divided peroxide of lead is distributed. It is well known that the electromotive force of lead and lead peroxide in dilute sulphuric acid is nearly three times that of zinc and copper in the same liquid. We were therefore induced to think that the plate must act in the same way as our copper-zinc couple. We found such to be the case. If a plate so prepared be immersed in pure water the decomposition of the liquid manifests itself by the reduction of the puce-colored peroxide to the yellow monoxide. There could be little doubt therefore that the lead peroxide couple, if we may call it so, would decompose sulphuric acid, with the production of sulphate of lead. This also was found to be the case.

As the destruction of peroxide of lead means so much diminution of the amount of electric energy, it became interesting to obtain some definite knowledge as to the rapidity or extent of this action.

When the peroxide of lead on the metal is very small in quantity, its transformation into the white sulphate goes on perceptibly to the eye, but when the coating is thicker, the time required is, as might be expected, too long for this kind of observation. In one experiment, following the procedure of Planté, we formed the peroxide on the plate by a series of seventeen charges and discharges, or reversals, each operation lasting twenty minutes, and the time was further broken up by seven periods of repose, averaging about twenty-four hours in length. After the last charge we watched the local action taking place, and found that the whole of the peroxide passed into white sulphate within seventeen hours. In another experiment the two plates formed according to Planté's method were immediately joined up with the galvanometer, and deflection noted. They were then at once disconnected. After the repose of one hour they were joined up again, and another observation taken with the galvanometer. This was repeated several times, with the following results:

Initial strength of current, . .	100
After 1 hour's repose, . . .	97
" 2 " . . .	40
" 4 " . . .	14
" 17 " . . .	1.5

It results from this that during each of the long periods of repose recommended by Planté the peroxide on the lead plate is wholly, or almost wholly, destroyed by local action, with the formation of a proportionate amount of sulphate. But this is not, as it would seem at first sight, a useless procedure; for, in the next stage, the sulphate is reduced by electrolytic hydrogen, and by a process which we hope to explain when discussing the complete history of the reaction, the amount of finely divided lead capable of being peroxidized is increased. That this is actually the case is shown by the following experiment. The peroxide formed on a lead plate by first charging was determined and called unity; it was allowed to remain in a state of repose for eighteen hours, charged a second time, the peroxide again determined, and so on:

Separate periods of repose.	Charge.	Amount of peroxide.
——	First	1·0
18 hours	Second	1·57
2 days	Third	1·71
4 "	Fourth	2·14
2 "	Fifth	2·43

In other trials, following the procedure of Faure, we employed plates in which the peroxide was formed by the reduction of a layer of red lead (containing 51 grains to one square inch of metallic surface) and subsequently completely peroxidizing the spongy metal so produced. In one series of experiments we left the peroxidized plates to themselves for various periods, and determined the amount of sulphate formed. This gave us the amount of peroxide consumed.

Experiment	I,	after 2 hours	7·2	per cent.
"	II,	" 3 "	15·1	"
"	III,	" 4 "	19·8	"
"	IV,	" 5 "	30·0	"
"	V,	" 24 "	36·3	"
"	VI,	" 7 days	58·3	"
"	VII,	" 11 "	67·3	"
"	VIII,	" 12 "	74·3	"

The last experiment was tested with the galvanometer during its continuance, as in the case of the plate formed by Planté's method, with the following results:

Initial strength of current				100
After	1	day's	repose	92
"	3	"	"	79
"	4	"	"	34
"	5	"	"	24
"	7	"	"	11
"	9	"	"	8
"	12	"	"	1

It is evident from these observations that a lead-peroxide plate gradually loses its energy by local action, and that the rate varies according to the circumstances of its preparation.

Two difficulties will probably present themselves to any one on first grasping the idea of this local action: 1. Why should a lead plate, covered with the peroxide and immersed in dilute sulphuric acid, run down so slowly that it requires many hours or even days before its energy is so seriously reduced as to impair its value for practical purposes? In the case of the copper-zinc couple immersed in the same acid, though the difference of potential is not so great, a similar amount of chemical change would take place in a few minutes. 2. In a Planté or Faure battery the mass of peroxide which is in contact with the metallic lead plate expends its energy slowly. How comes it to pass that if the same mass of peroxide be brought into connection through the first lead plate with another lead plate at a distance, it expends its energy through the greater length of sulphuric acid in a tenth or a hundredth part of the time?

The answer to these two questions is doubtless to be found in the formation of the insoluble sulphate of lead, which clogs up the interstices of the peroxide and after a while forms an almost impermeable coating of high resistance between it and the first metallic plate.

The following conclusions seem warranted by the above observations:

In the Planté or Faure battery local action necessarily takes place on the negative plate, with the production of sulphate of lead.

The formation of this sulphate of lead is absolutely requisite in order that the charge should be retained for a sufficient time to be practically available.

The rapidity of loss during repose will depend upon the closeness of the sulphate of lead and perhaps upon other mechanical conditions. These are doubtless susceptible of great modifications. We do not know how far they are modified in practice, but it is conceivable that still greater improvements may yet be made in this direction.

Part II.—The Charging of the Cell.

In the preceding article we directed attention principally to the local action that takes place on the negative plate of a Planté or Faure battery. We pointed out the close analogy between zinc coated with spongy copper, and lead coated with spongy peroxide, in their action on water or dilute sulphuric acid; and we showed the importance of the lead sulphate produced in moderating this action. We now propose to treat of the chemical changes involved in the preparation of the cells.

The procedure of Planté in forming his battery is at first sight extremely simple. He takes two coils of lead, separated from one another, and immersed in dilute sulphuric acid; a current is sent through the liquid from one lead plate to the other, and the final result is that the one becomes covered with a coating of lead peroxide, while hydrogen is given off against the other plate. On the view that the sulphuric acid merely serves to diminish the resistance, and so facilitate the electrolysis of water, the ready explanation would be given that the two elements of the water are simply separated at the two poles. But it seems more in accordance with the facts of electrolysis to suppose that the sulphuric acid, H_2SO_4, is itself the electrolyte, and that the oxygen results from a secondary chemical reaction. As a matter of fact, if water be employed no peroxide is formed, but only the hydrated protoxide, even though a current from twenty-four Grove's cells be made use of. The addition of a single drop of sulphuric acid to the water is enough to cause the immediate production of the puce-colored oxide.

If we take two plates of lead in dilute sulphuric acid, and pass the current from only one Grove's cell, a film of white sulphate, instead of peroxide, makes its appearance on the positive pole, and the action practically ceases very soon. If, however, the current be increased in strength, the sulphate disappears, and peroxide is found in its place. In Planté's procedure, spongy lead and lead peroxide are indeed found on the respective plates. But in consequence of the local action which takes place during the periods of repose lead sulphate will be produced from the peroxide, and afterwards, in the course of the "formation," this must be reduced to metallic lead by the hydrogen.

It may seem at first sight improbable that an almost insoluble salt of the character of lead sulphate should be decomposed under these circumstances. To test this fact by direct experiment, we covered

two platinum plates with lead-sulphate, immersed them in dilute sulphuric acid, and sent a current through. We found not only that the sulphate was reduced by electrolytic hydrogen, but that it was peroxidized by electrolytic oxygen. The white sulphate was, in fact, decomposed to a large extent at each plate, the positive being covered with deep chocolate-colored peroxide, the negative with gray spongy lead. . . . The coating of peroxide interposes a great difficulty in the way of the further oxidation of the metallic lead. Hence Planté needs the successive periods of repose to admit by local action of the formation of lead-sulphate, and the oxidation of the increasing amounts of finely-divided lead thus brought into the field of action.

To obviate this waste of power and time, Faure covers both plates with red lead, and converts this into spongy peroxide and spongy lead, respectively, by the current. Now the first thing that happens when the plates are immersed in the dilute sulphuric acid is a purely chemical action. The minium suffers decomposition according to the formula $Pb_3O_4+2H_2SO_4=PbO_2+2PbSO_4+2H_2O$.

But as both the lead sulphate and lead peroxide are insoluble, this takes place mainly at the surface, and requires time to penetrate. Thus in an experiment performed with the object of testing this point, the following amounts of minium were found to be converted into lead-sulphate in successive periods of time:

Time.	Minium changed into sulphate.
15 minutes, . .	11·8 per cent.
30 " . .	13·7 "
60 " . .	14·6 "
120 " . .	18·1 "

It might happen, and we are told it has happened, that the amount of minium employed has been great enough to abstract the sulphuric acid from solution, leaving only water. In that case water, of course, would be the electrolyte, and there can be little doubt that the lead plate would suffer oxidation in the manner which was described by us some years ago (*Chem. Soc. Journ.*, 1876) in a paper on "Phenomena accompanying the Electrolysis of Water with Oxidizable Electrodes." This paper detailed the results obtained on passing a current from one Grove's cell between two plates of the same metal immersed in pure water. We stated in the case of lead: "The positive electrode showed signs of slight oxidation, and the negative electrode a few small bub-

bles, in fifteen minutes; a slight cloudiness was then beginning to form, which afterwards increased; some oxide was found adhering in an hour, and afterwards gray metallic lead, which at the end of twenty-two hours was found to have stretched across to the positive electrode, forming a metallic connection which was so much heated by the passage of the voltaic current that the liquid became warm." We are informed that such lead crystals have sometimes been found in Faure's cells.

Supposing, however, that there is enough and to spare of sulphuric acid, the mixture of lead peroxide and lead-sulphate presents a double problem. Were we dealing with peroxide alone, it would be reduced on the one plate at the expense of two molecules of water or sulphuric acid, while at the opposite pole the oxygen would simply be liberated. But as there is always lead sulphate present, this liberated oxygen is mainly used up in oxidating that substance, and it is theoretically sufficient to peroxidize the two molecules of sulphate. . . . These two molecules of $PbSO_4$ are also obtained from one molecule of Pb_3O_4 (red lead), and it appears that two atoms of oxygen are sufficient to transform this into peroxide. But the corresponding amount of hydrogen (four atoms) by no means suffices to reduce a similar amount of red lead on the other side, for in this case both the peroxide and the sulphate formed by the action of the acid have to be reduced. To accomplish this at least eight atoms of hydrogen will be necessary, and this will demand the electrolysis of an additional two molecules of water or sulphuric acid. It might therefore be expected, *à priori*, that the minium on the side to be oxidated ought to be twice the amount of that to be reduced.

In order to ascertain what is the real course of procedure in charging a Faure battery, we took two plates of lead of equal size, and covered each with a known weight of minium, which was almost pure Pb_3O_4. We passed a current of known strength, about one ampère, through the arrangement for many hours, noting the amount of hydrogen gas which was liberated at the one pole, and the amount of oxygen liberated at the other. From the data it was easy to calculate the amount of electrolytic hydrogen and oxygen utilized. We performed the experiment several times, varying the strength of the current and some other circumstances. The most complete result was as follows:

	Hydrogen.		Oxygen.	
Time. Hours.	Lost. cc.	Absorbed. cc.	Lost. cc.	Absorbed. cc.
1	Nil	312	Nil	156
2	"	318	18	141
3	"	306	48	105
4	"	300	66	84
5	"	300	72	78
6	2	313	90	67
7	5	295	87	63
8	3	312	96	61
9	6	303	93	61
10	21	297	99	60
11	37	273	99	56
12	101	220	105	56
13	150	158	105	49
14	195	132	105	58
15	210	92	100	51
16	228	90	106	53
17	225	85	100	55
18	270	66	108	60
19	264	51	108	49
20	270	50	111	49
21	273	43	114	44
22	270	30	114	36
23	276	30	114	39
24	297	21	123	36
25	309	9	126	33
26	270	18	120	24
27	300	18	132	27
28	309	11	138	22
29	321	15	141	27
30	318	15	147	19
31	300	6	135	18
	5230	4489	3120	1737

The amounts of hydrogen and oxygen capable of being absorbed by the materials on the plates were 4574 and 1294 respectively.

We read the indications of this table in the following way: At first,

both the reduction and oxidation take place very perfectly, with little loss of either of the elements of water. The absorption of the hydrogen proceeds with little diminution, until by far the greater part of the lead peroxide and sulphate are reduced, but the last portions are very slowly attacked, probably because they are imbedded in a mass of reduced lead. On the side that is being oxidated it is otherwise: a considerable waste of oxygen soon shows itself, but nevertheless a continuous slow absorption of that element takes place long after the theoretical amount of it has been fixed. A very small amount of this excess is to be attributed, according to our experiments, to the oxidation of the metallic plate itself. But we attribute the greater portion to the local action which must be constantly going on between the peroxide and the lead plate, with the formation of sulphate of lead, the sulphate in its turn of course being attacked by the electrolytic oxygen. Thus the excess of oxygen in the fifth column of the above table may be looked on as a measure of the local action which has taken place during the charging, and the figures in the lower portion as roughly indicating its progress from hour to hour. Local action will of course take place at first on the opposite plate, but it requires no more hydrogen to reduce two molecules of lead sulphate than one molecule of lead peroxide, and the possibility of local action gradually diminishes as the reduction proceeds.

All our other experiments told the same story as far as the absorption of hydrogen is concerned, but there are differences on the other plate. In one or two instances not half of the theoretical amount of oxygen was absorbed. On searching into the circumstances on which this depended, we were unable to arrive at any other conclusion than that it was connected with the condition of the surface of the lead plate.

Experiments with a current of about two ampères showed that a larger quantity of both hydrogen and oxygen was fixed in a given time, but there was a larger proportionate loss, especially in the case of oxygen. Experiments with a current of about half an ampère, on the contrary, gave a somewhat less rapid action, but a smaller waste of force through the escape of free gas.

A complete study of the results of these experiments would be instructive, but the following comparisons may suffice to illustrate the points just mentioned. The theoretical amount of oxygen required for the red lead used is about 1200 cc., and the table shows the length of

time in which 300, 600, and 1000 cc. were fixed by different strengths of current, together with the accompanying loss:

Strength of current. Ampères.	Amount of oxygen stored. cc.	Time. Hours.	Loss of oxygen. cc.
2	300	1·5	174
1	"	2	18
½	"	3·8	15
2	600	4·1	617
1	"	5·5	249
½	"	7·6	47
2	1000	13·9	3081
1	"	12·2	900
½	"	16·0	400

In some cases we mixed the red lead with a little water, and allowed it to dry. In other experiments we mixed it at once with dilute sulphuric acid, but without any particular practical advantage.

The forming of a good secondary battery is a matter evidently depending upon very nice adjustment of conditions. It is but a few of these that we have carefully studied; nevertheless, we feel ourselves in a position to make one or two suggestions in regard to the economic aspects of the question. It is evident that the energy stored up in a cell is determined mainly by the amount of peroxide present. This appears to be obtained with the smallest amount of waste when the current is not too strong; in fact, in our experiments it was obtained when the density of the current was about 6½ ampères, calculated on the original surface of the lead plates.

There would seem to be no commensurate advantage in continuing the current after the oxygen has ceased to be absorbed pretty freely, because the presence of some unoxidized sulphate of lead, although it increases the resistance, rather impedes than promotes local action.

On the other hand, however, it is necessary that the reduction of the minium on the opposing plate should be complete, for a mixture of lead peroxide and metallic lead would be peculiarly conducive to the production of lead sulphate, and thus increase the resistance; while if any peroxide should remain, it would diminish the electromotive force of the cell.

It would appear probable, therefore, that the most economical arrangement would be obtained by making the red lead to be hydro-

genated much smaller in amount than that to be oxidated. On trying the experiment with only half the quantity, we obtained a most satisfactory result as far as the charging was concerned. How far such an arrangement may be really desirable we will consider more fully when we treat of the chemistry of the discharge.

PART III.—THE DISCHARGE OF THE CELL.

The two plates of a Planté or Faure battery consist essentially of lead peroxide as the negative element, and metallic lead in a spongy condition as the positive. These are brought into communication with one another through the lead plates which support them, together with the connecting wire.

The lead peroxide reacts both with the lead plate that supports it, and with the lead on the opposite plate. At first sight, it might be expected that the reaction between it and the supporting plate would be the greater, as the space between them is so small, and the resistance of the intervening liquid in consequence almost inappreciable. The action is, indeed, probably greater at the first moment, but, as explained in our first chapter, sulphate of lead is immediately produced, and that which lies at or near the points of junction forms no doubt a serious obstacle to further local action, and admits of the lead on the opposite plate coming more fully into play.

If we consider *à priori* what is likely to be the reaction between lead peroxide and lead, with water as the connecting fluid, we should expect: $PbO_2 \mid H_2O \mid H_2O \mid Pb = PbO \mid H_2O \mid PbH_2O_2$.

On experiment this is found to be actually the case, yellow oxide appearing on the negative plate, and white hydrate on the positive.

If, however, the reaction takes place in presence of dilute sulphuric acid, the result will inevitably be sulphate on both sides, for even if oxide be first formed, it will be attacked by that acid. Of course this production of lead sulphate on each side might be expected gradually to produce a perfect electrical equilibrium. This, in fact, does take place under certain circumstances, but not under others. The reaction on the negative plate is always of this character, as far as our analyses have shown. We have invariably found the deposit to consist of sulphate of lead mixed with unaltered peroxide. If, however, the cell be allowed to discharge itself rapidly, the lead on the positive plate is converted, not only into the sulphate, but, very partially, into lead peroxide. This is sometimes evident to the eye from the puce color of

the superficial layer, and we found also that this was confirmed by several chemical tests.

It is difficult to conceive how the reduction of the peroxide of lead on the one plate to oxide or sulphate should be attended by a direct oxidation of lead on the other plate up to peroxide itself, as that would involve a reversal of the electro-motive force. It is more easy to imagine that the peroxide results from the oxidation of sulphate of lead already formed, through the agency of electrolytic oxygen.

When this peroxide is formed on the positive plate it is not difficult to foresee what must happen. A state of electrical equilibrium will be approached before the peroxide of lead on the negative plate is exhausted. But the two sides are in very different positions with regard to local action. On the negative plate, the peroxide being mixed with a great deal of lead sulphate, it will suffer decomposition only very slowly through the agency of the supporting plate, but the lead peroxide on the positive plate, being mixed not only with lead sulphate, but with spongy metallic lead, will be itself speedily reduced to sulphate. Hence, on breaking the circuit, when local action alone can take place, the peroxide formed on the positive plate during the discharges will be destroyed much more easily than the original peroxide on the other plate. The difference of potential between the plates will be restored, and on connection the cell will be again found in an active condition.

Now it has been frequently observed that partially discharged accumulators do give an increased current after repose, that is, after the circuit has been broken and re-established. It remained for us to ascertain whether the chemical change above described coincided in any way with the physical phenomena. For this purpose we prepared plates according to the method of Faure, and examined carefully the changes of electro-motive force and strength of current, which took place during their discharge under known resistances, and the chemical changes that took place under the same circumstances.

We found that the initial electro-motive force of freshly prepared cells was 2·25, 2·25, 2·21, and 2·31, volts, averaging 2·25, but that after standing for thirty minutes or so, or when allowed to discharge for a few minutes, it was reduced to about 2·0 volts. We take this to represent the normal electro-motive force of the arrangement of lead, lead peroxide, and dilute sulphuric acid, and believe that the higher

figure obtained at the first moment is due to the hydrogen and oxygen occluded on the respective plates, and which either diffuse out or are speedily destroyed.

We found, however, that in the discharge the electro-motive force diminished under certain conditions. Thus, in an experiment in which the external resistance was 1 ohm, and the internal 0·58 ohm, the E.M.F. sank in forty-five minutes from 2·25 to 1·92, but after being disconnected for thirty minutes, it was found to have risen to 1·96, and after eighteen hours' repose it had actually risen to 1·98 volts. These observations were made many times in succession during the course of the experiment, which lasted six days.

With twenty times the external resistance, the diminution of electro-motive force was much slower; but after discharging three days, the fall was more pronounced, and the rise on repose very apparent.

With 100 ohms resistance the electro-motive force varied very little for three days.

It is more difficult to obtain satisfactory chemical evidence of a quantitative character. It is clear that as chemical examination means the destruction of the substances, the same plate cannot be analyzed in two consecutive stages. Nor can two plates be easily compared with one another, although they have been formed under the same circumstances. Even the same positive plate, during or after discharge, presents to the eye very different appearances in different parts. To a certain extent we obviated this difficulty by cutting the plate in two, longitudinally, analyzing the one half at once, and allowing the other to repose for a given time before examining it for peroxide of lead.

As to the estimation of peroxide in the presence of metallic lead, we finally adopted as the best method that of reducing it by means of oxalic acid, although we were not certain that the whole amount is obtained in this way, even though the solution be kept hot for a considerable time.

By this method many chemical examinations were made of the positive plate. The results are as follows: First of all, when the external resistance did not exceed 20 ohms the peroxide of lead was generally visible in patches, and its presence was demonstrated and approximately measured by various chemical tests. On repose, the quantity of this peroxide visibly diminished, and in the majority of instances the chemical analyses also showed a smaller amount. In all cases sulphate

of lead makes its appearance early in the action, and gradually increases in quantity, becoming finally the only product of the discharge.

The deposit on the negative plate shows the presence of nothing but sulphate of lead in addition to the unchanged peroxide. At the conclusion of the action, we have always found more or less of this substance unaltered. Thus, as one instance, after a discharge lasting five days, and approximately complete, we found that only 68 per cent. of the deposit was lead sulphate.

We conclude, therefore, that the chemical action of the discharge is essentially what is expressed by the following theoretical formula:

$$PbO_2 \mid H_2SO_4 \mid H_2SO_4 \mid Pb = PbO \mid H_2O \mid H_2SO_4 \mid PbSO_4,$$

which becomes $PbSO_4 \mid H_2O \mid H_2O \mid PbSO_4$.

This reaction is, however, sometimes complicated by the formation of a small amount of peroxide of lead on the positive plate. We believe this to be due to the oxidation of sulphate, an action which was explained in our last chapter.

Another conclusion has reference to the resuscitation of power observed on repose. This is not due to any purely physical action but is a necessary consequence of the formation of PbO_2 on the positive plate. As sooner or later the result of the action becomes solely $PbSO_4$, this temporary formation of peroxide does not seriously affect the quantity of electrical force that may be regained from the accumulator, but it does affect the evenness of its flow. The flow is more regular if the discharge be made slowly, but in that case the loss on the negative plate from local action will probably be greater.

As to the practical conclusions we may note: 1. Although, as stated in the first chapter, the most economical arrangement for the initial charging of the cell is to "make the red lead to be hydrogenated much smaller in amount than that to be oxidated," yet, as foreshadowed in the same chapter, this arrangement is not desirable for the discharge of the cell. Nor is it for its subsequent charging, since, as will have been seen, the substances to be acted upon are now very different. On the negative plate there will be the sulphate of lead produced by the discharge, plus sulphate of lead produced by local action, together with more or less unaltered peroxide. On the positive plate there will be the sulphate of lead produced by the discharge, together with excess of lead, if any. Unless, therefore, the peroxide of lead unacted upon is allowed to be very considerable, the quantity of lead compound on the two sides ought to approach equality. 2. Care should be taken

that sulphuric acid is in sufficient excess to allow of there still remaining some of it solution after all the available lead has been converted into sulphate. If it is removed and only water is present, an oxide or hydrate will be produced with probably some serious consequences to the cell.—*London Nature.*

RECENT IMPROVEMENTS IN THE MECHANIC ARTS.

THERMOSTATIC CUT-OUT FOR ELECTRIC LIGHTING SYSTEMS.—This recent improvement combines with the main conductor of an electric lighting system a switch constructed and arranged to electrically connect the main conductor with the electric conductor of a building. When, however, the temperature of the electric wires extending through the building exceeds a predetermined degree, the switch automatically short-circuits the current through the main conductor. This effect is accomplished by a wire connected to the switch-lever and extending through the building, connected, or joined, at intervals by fusible joints or links. A weight is provided for shifting the switch and short-circuiting the current upon the fusion of the joints or links.

RAILWAY SNOW PLOW—A late invention comprises a car or truck which carries two vertical and two horizontally-inclined endless aprons with supporting rollers, by which the snow is carried up and compressed, the upper horizontal apron being adjustable in inclination to regulate the amount of compression to which the snow is submitted. All of the aprons are driven by rods and gear wheels from an engine, mounted upon the truck, and are supported and adjusted by ropes and tackle from an upright frame on the car. The snow is divided and directed onto each of the aprons, and prevented from falling between them by an angle board above the adjoining ends. To the front of the car is a funnel with its sides flanged to lap the top and bottom plate. To the front of the funnel is a reciprocating cutter-bar driven out by an angle-lever and crank-wheel from the apron roller-gearing.

INCANDESCENT ELECTRICAL ILLUMINATION.—In this improvement illuminated signals, symbols, designs, or figures are composed of electrical conductors bent or formed into the required shape, and having numerous electrical vacuous cells removably attached or connected thereto. The conductors of the electric circuit are formed of suitable

material, having considerable body, and running horizontal and parallel to each other. These conductors have cavities or depressions therein, or grasping devices attached thereto, located opposite each other so as to hold incandescent electric lamps or vacuous cells in electrical connection.

ELECTRIC LANTERN.—This novel lantern is composed of wire frame-work of similar contour to the ordinary oil lantern. The upper part of the frame supports a secondary battery, and an incandescent lamp is supported directly below. Electrical connections for charging the battery, and similar connections between such battery and the lamp, are provided. There is a bail for carrying the lantern, and a removable top to give access to the battery.

STOP-COCK.—In this improved cock or faucet an interior elastic flexible tube is provided, and an opening is cut away in the exterior metal tube to expose a portion of the flexible tube. A lever having a depending stirrup, arranged to compress the elastic tube, is employed so as to stop the flow of the liquid. The lever, for this purpose, is eccentrically pivoted to a hand-operating lever, suitably journaled in bearings cast on the cock.

RAILWAY TRAIN TELEGRAPH.—This apparatus is designed for telegraphic communication between a number of moving trains and any number of intermediate stations. It employs two suspended insulated main wires—one wire connected at one end with one terminal battery, and the other wire at its opposite end with another terminal battery—in combination with a traveling truck or sheave, connected electrically with the moving train, and in contact with the main wires, and having inleading and outleading wires. The main wires are severed at the stations, and connecting wires from the severed ends pass to the instruments in the stations and are connected with each other by switch-boards.

AUTOMATIC TELEGRAPH TRANSMITTER.—This device is designed for learners' use. A prepared strip perforated with messages is inserted into the instrument and carried under a transmitting-stylus, which automatically makes and breaks a circuit through a reading sounder. Should the student fail to correctly read any letter or word he presses a lever, and thereby causes the motor to reverse the reel, lift the stylus, and rewind the transmitting strip, after which, on reversal of the lever the message or word is repeated.

Washington, D. C. FENELON B. BROCK.

Crayons in Vitrifiable Colors.—M. Lacroix, a Parisian chemist has introduced crayons similar to the ordinary lead pencils, the lead being replaced by vitrifiable colors. The colored designs which are executed with these crayons, on slightly roughened glass, bear the heat of a muffle and are fixed like a painting upon glass; the grays especially give excellent results. A similar process which was tried upon porcelain some years ago was unsuccessful, probably because enamelled surfaces were used. On biscuit it is likely that good results might have been obtained.—*Chron. Industr.*, No. 21, p. 257. C.

Crumbling of Tin.—Leaves of tin foil, when they are exposed for a long time to cold, sometimes become brittle, fall in pieces, and are finally reduced to powder. Fritzche and Lewald have spoken of a crystalline texture which the metal takes under the influence of cold. Prof. Rammelsberg has suggested the idea of a stannic dimorphism, basing his views upon examinations which disclosed a diminution of specific weight in the crumbled tin. Oudemans and Walz cite a case in which good commercial tin, with the usual quantity of 3 per cent. of lead, was changed into a gray powder during the transit from Rotterdom to Moscow in a very cold winter. In discussing this observation M. Wiedman calls the attention of physicists to the probable influence of continuous vibrations, such as would result from variations of temperature. Another remarkable fact shows that the phenomenon may be produced by continuous small shocks. In a corner of a window in the cathedral of Fribourg there was found a wooden box which, when it was opened, disclosed fragments of a medal and of a tin ring, as well as small bits of a reddish-gray color, of the remarkably low specific gravity of 5·8. In this case, as well as in those already mentioned, a metal having the brilliancy, the specific weight, and the other ordinary qualities of tin, could be obtained by simply heating the debris at the temperature of boiling water. M. W. Markownikoff, of Moscow, gives an account of some tin pots which were left in a cold room of one of the government buildings, on which swellings first appeared, then holes, and then there was a gradual crumbling to powder. When once begun the destructive action cannot be stopped by carrying the pots into a warm room, but it ceases by removing the parts which are attacked.—*Les Mondes*, May 20, 1882. C.

Economical use of the Falls of the Rhine.—In Switzerland, a number of citizens of Schaffhausen are disposed to utilize the transmission of the mechanical force of the falls by dynamo-electric machines. Already several of these machines, which were built at Basle by Burgen and Alioth, have reached Schaffhausen, and two of them are in constant use. The mechanical force of a wheel, which is set in motion by the water, is transformed into electricity and conveyed to a distance by thick copper wires, in order to be transformed again into mechanical force at its destination.—*La Lumière Electrique*, vi, 359.

To Distinguish Cotton-seed Oil from Olive Oil.—Prof. Zecchini takes pure colorless nitric acid of the density 1·40, and mixes it with half the quantity of oil in a tin tube closed with gum. After shaking it for several seconds the tube is allowed to rest in a vertical position for 5 or 6 minutes. If the oil was from olives the liquid is at first pale or colorless, changing to an ashy grey with a slight yellowish hue. Cotton-seed oil is at first of a golden yellow, then copper-colored, becoming almost black. The reaction is delicate enough to detect an adulteration of 5 per cent. of cotton-seed oil.—*Les Mondes*, May 13, 1882. C.

Treatment of Silver Ore.—A. Raimondi gives the following reactions in the Peruvian treatment of silver ores: 1. After adding chloride of sodium a flux is introduced which is composed principally of sulphate of copper, giving the following reaction:

$$CuOSO_3 + NaCl = CuCl + NaOSO_3.$$

2. The chloride of copper which is thus formed reacts upon the mercury and upon the silver, both in the metallic state and in their combinations with sulphur, as follows:

$$2CuCl + Hg = Cu_2Cl + HgCl,$$
$$2CuCl + Ag = Cu_2Cl + AgCl,$$
$$\begin{cases} 2CuCl + AgS = Cu_2Cl + AgCl + S \\ CuCl + AgS = CuS + AgCl. \end{cases}$$

The action of the cupric bichloride upon the mercury is more rapid than upon the silver; the reactions upon the silver are more or less intense, according to the chemical state of the metal and the proportion of cupric chloride. The presence of salt is not indispensable for the actions of the chloride upon the argentiferous compounds, but it appears to facilitate them. Perchloride of iron may be substituted for the cupric chloride, but it is less efficacious.—*Ann. des Mines.* C.

Extension of Mariotte's and Gay-Lussac's Law.—Biehringer gives the following formula:

$$\frac{p\,s\,r}{q} = \frac{p's'r'}{q'} = \text{const.}$$

In this equation p denotes the pressure, s the specific gravity, r the volume, q the absolute weight of a gas; $p's'r'q'$ are the corresponding values for any other gas, and the constant remains unchanged as long as the temperature of the gases is the same. He gives a modification of the formula which is an algebraic expression for the following laws: 1. Gases whose densities are proportional to their specific gravities exert equal pressures at equal temperatures 2. Gases with equal densities exert pressures at equal temperatures which are inversely proportional to their specific gravities. Instead of the density the absolute weight and volume may be introduced for deducing further laws.—*Beiblätter*, vi, 207. C.

Regenerating Battery.—J. Rousse replaces the zinc of the Bunsen cell by ferromanganese, of the strength of 85 per cent. Pure manganese has such an affinity for oxygen that it decomposes boiling water. This gives to the new battery an electro-motive force similar to that of amalgamated zinc. In order to produce energetic currents diluted sulphuric acid is employed; the depolarization is obtained by concentrated nitric acid. For feeble currents, and when the battery is to be employed in ordinary apartments, permanganate of potash is employed as a depolarizer. The salts produced by the battery are sulphate and nitrate of manganese or of potash. To remove the sulphuric acid from the liquid he treats it with the nitrate of lead, which is produced in his lead battery. The sulphate of lead which results from this reaction is transformed into ceruse, by boiling with carbonate of potash. The soluble salts separated by decantation contain only nitrates of manganese and of potash. Pouring in carbonate of potash all the oxide of manganese is precipitated in the state of carbonate. This precipitate is washed and calcined, to reduce the metal to a sesquioxide, which is heated with potash and nitrate of potash and thus transformed into permanganate of potash. Peroxide of manganese is then easily obtained by known methods. All these chemical operations are simple and can be easily executed; they are so combined as to produce dynamic electricity economically and without leaving useless residues.—*Comptes Rendus*. C.

Meteoric Organisms.—Carl Vogt has carefully examined the peculiar formations which were found in meteorites by M. Hahn, in order to satisfy himself whether their structure is organic. By a detailed comparison with living and fossil sponges, corals and crinoids, he arrives at the conclusion that the forms are entirely inorganic. He thinks that they are due to the presence of an opaque incrusting material, aided by optical illusions which arise from an incomplete method of microscopic research. His observations go to show that the figures are all composed of transparent crystalline fragments, arranged in various ways, but most commonly in columns, or tufts, ramified or radiating from a centre. The interstices are filled with an opaque substance which is but slightly affected by acids, and which mimics organic structure. These views, however, are still disputed by Hahn and other European and American microscopists.—*Comp. Rend.* C.

Tempering by Compression.—L. Clémandot has devised a new method of treating metals, especially steel, which consists in heating to a cherry red, compressing strongly, and keeping up the pressure until the metal is completely cooled. The results are so much like those of tempering that he calls his process tempering by compression. The compressed metal becomes exceedingly hard, acquiring a molecular contraction, and a fineness of grain, such that polishing gives it the appearance of polished nickel. Compressed steel, like tempered steel, acquires the coercitive force which enables it to absorb magnetism. This property should be studied in connection with its durability; experiments have already shown that there is no loss of magnetism at the expiration of three months. This compression has no analogue but tempering. Hammering and hardening modify the molecular state of metals, especially when they are practiced upon metal that is nearly cold, but the effect of hydraulic pressure is much greater. The phenomena which are produced in both methods of tempering may be interpreted in different ways, but it seems likely that there is a molecular approximation, an amorphism, from which results the homogeneity that is due to the absence of crystallization. The advantages of the new method are obvious. Being an operation which can be measured, it may be graduated and kept within limits which are prescribed in advance; directions may be given to temper at a specified pressure as readily as to work under a given pressure of steam.—*Chron. Industr.* C.

Book Notices.

The Civil Engineer's Pocket Book. By John C. Trautwine, C.E. Seventeenth Thousand. 12mo, 693 pages. Philadelphia: E. Claxton & Co. 1882.

We have before us another edition of this valuble technical text-book, by far the most useful pocket book for the civil engineer which has yet been published, containing a vast amount of information on surveying, hydraulics, hydrostatics, instruments, strength of materials, roof and bridge trusses, railroads, etc.; deductions from complicated and abstruse formulæ, experiments and practice condensed into a portable and convenient form, from a vast number of volumes of technical literature, as well as from the results of the author's practice during a long and active professional life.

Among the additions will be found a table "To find circumfs of circles when the diam contains decimals," on page 675; other additions will be found throughout the work, as well as the correction of such errors as have been noticed in previous editions.

In conclusion, we can only say that this work, while indispensable to the young civil engineer, will also be found of much use by the more experienced members of the profession. C. H. R.

The Fire Protection of Mills and Construction of Mill Floors. By C. J. H. Woodbury, M.E., Inspector Factory Mutual F. I. Companies. New York: John Wiley & Sons. 1882.

A practical application of certain neglected means and recent improvements to the protection of factories, etc. Water supply, standpipes, tanks, pumps, valves, hose and general organization for service are first treated. The author illustrates an admirable mode of *grooved* large and small pulleys for driving pumps—the smaller pulley moved into gear by a screw. This plan removes all fear of broken or slack belts at a critical moment. Automatic sprinklers are described, with full sized designs of heads; also tinned wooden "fireproof" and automatic closing doors. Mill fires, spontaneous ignition and electric lighting have a large share of the discussion, and illumination by electricity is expected to become very general in mills. Heating, fires caused by steam pipes and lanterns, the spontaneous ignition of goods in dye-houses, together with modes of self-insurance by factory owners, close what may be called the first part of this excellent handbook.

The second half treats of the safe construction of mills and storehouses, favoring those modes which will cause the slowest burning, if ignited, rather than a dependence on iron columns, girders, floors and roofs. This is sound fire-doctrine. We think he is mistaken in advocating canvas roofs, nailed down with large galvanized tacks. The oxygen of the air will, in a few years, corrode even galvanized nails and the material immediately surrounding them, loosening the roof and causing it to leak. Tarpaulin may suit some places, but will not, in our estimation, make durable factory roofs. The author devotes much attention to vibration in mills and cures therefor, and believes in the influence of synchronal notes of waterfalls and "tones beyond the limit of the human ear"—possibly like those of the Irish fiddle, said to have, once upon a time, imperilled an iron bridge. We have only one objection to this book, and that is not serious, because it can be "skipped" without serious detriment—there are over 40 pages of abstruse mathematics to prove calculations of strength of materials. By the time Mr. Woodbury issues his second edition, which we hope may be soon, he will discover that not one in twenty of his readers will have studied out these pages. The tests and tables of strength for wooden columns of factories, given at the conclusion, are especially valuable to mill owners and builders. S. H. N.

ERRATUM.—Article "Economy of the Windmill, etc., (Wolff), page 25, table 1, column 4, last line, for 1.13 read 1.34.

OBITUARY.—ROBERT BRIGGS.

We note with deep regret the death of Robert Briggs, C. E., which occurred at Dedham, Mass., on the 24th of July. Mr. Briggs was prominently identified with the FRANKLIN INSTITUTE for many years, having served as one of its Board of Managers, as Editor of the Journal, and as an active member of some of its most important committees. We anticipate the appointment of a committee, to whom will be referred the task of preparing a full account of Mr. Briggs' professional career. Mr. Briggs was in his 61st year at the time of his death. W.

JOURNAL

OF THE

FRANKLIN INSTITUTE.

· OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXIV. OCTOBER, 1882. No. 4.

MOHR'S GRAPHICAL THEORY OF EARTH PRESSURE.

By GEORGE F. SWAIN, S.B.

Instructor of Civil Engineering in the Massachusetts Institute of Technology, Boston.

The subject of the pressure of earth has been worn nearly threadbare. It has been discussed from all points of view, again and again, until there seems no room for anything new to be presented. And yet, although our technical journals have had their full share of the discussion, the writer does not remember ever to have seen in English a presentation of the graphical method given by Professor Mohr in 1871. The analytical methods in general use, either the ones founded on the wedge of greatest pressure, or on the principles of internal stress, as first presented by Rankine, although simple enough, and although leading to formulas which can easily be interpreted graphically, often leave some confusion in the mind; and they are far inferior, as regards giving a clear and connected view of the subject, to Professor Mohr's method. The practical engineer who should happen to be unacquainted with the method will be glad to learn that the whole subject of the pressures in a mass of earth bounded above by a plane can be represented clearly and concisely without the use of any but the simplest mathematics, and with the aid of only the most elementary theorem of statics; and that the method leads to very simple methods of

finding the pressure on a wall in any position. It may not be amiss, then, to bring up the subject once more, and to explain the method; and we shall have occasion to notice the limits of its applicability. The present paper, then, contains nothing original, for the method is widely known and has been often discussed. It is presented in the following pages in my own way, but it may all be found in the following publications:

1. "Mohr—Beitrag zur Theorie des Erddrucks. Zeitschrift des Architekten-und Ingenieur-Vereins zu Hannover, 1871."

2. "Mohr—Zur Theorie des Erddrucks." Same periodical, 1872.

3. "Winkler—Neue Theorie des Erddrucks, nebst einer Geschichte der Theorie des Erddrucks und der hierüber angestellten Versuche." (Vienna, 1872. R. v. Waldheim.)

We assume from the beginning an unlimited mass of earth with a plane upper surface, and neglect the cohesion. The following results follow at once:

1. The pressure on any plane parallel to the surface is vertical, and equal in intensity to $\gamma\, y$, if γ is the weight of a unit of volume of earth, and y the normal distance of the plane in question from the surface. For the plane has only to support the weight above it; *i. e.*, every unit of area of the plane supports a prism, whose section is $\cos.\alpha$, and whose height is $\dfrac{y}{\cos.\ \alpha}$.

2. The pressure on a vertical plane which cuts a horizontal line from the surface is parallel to the surface. For if we consider figure 1 to represent a section of the mass of earth along a line of steepest declivity, and $a\,b$ and $c\,d$ to be vertical planes, while $a\,c$ and $b\,d$ are parallel to the surface, then, inasmuch as the right prism of which $a\,c\,d\,b$ is a section must be in equilibrium, and the pressures on $a\,c$ and $b\,d$ are vertical and in equilibrium with the weight of the prism; it follows that the pressures on $a\,b$ and $c\,d$ must balance each other; hence, being both applied at the same distance from the surface, they must act in the same straight line parallel to the surface.

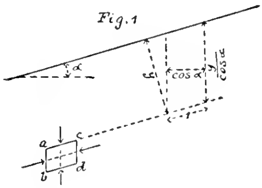
3. The shearing or tangential forces at any point on two planes at right angles to each other are equal in intensity. For if we consider an infinitely small rectangular parallepipedon, of which Fig. 2 represents a section, then by taking moments about 0 we shall have

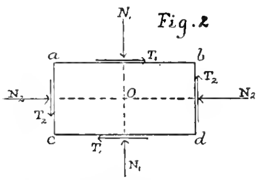
$$T_1.ab.ac = T_2.ac.ab \because T_1 = T_2,$$

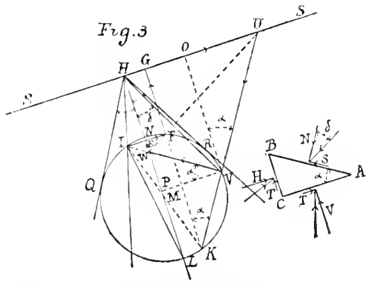
these being the intensities on the two planes.

Let us now consider an infinitely small triangular prism of a length perpendicular to the paper, equal to unity, and although all the other dimensions are infinitely small, let us take AC (Fig. 3) parallel to the surface and equal to 1, BC perpendicular to AC, and the angle $CAB = \alpha$. For the areas of the sides of this prism we have

$$AC = 1; \quad BC = \tan.\alpha; \quad BA = \sec.\alpha.$$

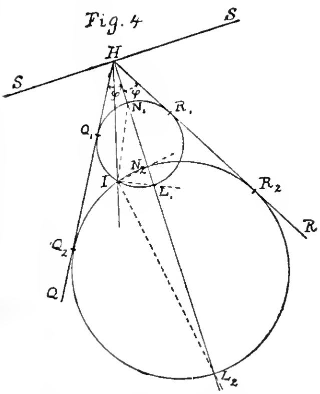


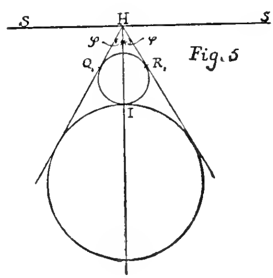




If we resolve the stresses on these sides normally and tangentially we have six forces acting on this prism, in the plane of the paper, as follows:

On AC: V and T.





On BC: H tan.α and T tan.α.

On AB: N sec.α and S sec.α. (See Fig. 3.)

These forces must be in equilibrium, and consequently they must form a closed polygon. Such a polygon is E, F, G, U, V, W, E, in

Fig. 3, in which $EF=T$; $FG=V$; $GU=H\tan.a$; $UV=N\sec.a$; $VW=S\sec.a$; $WE=T\tan.a$.

Supposing these forces to be laid down correctly, we can investigate some of their properties which will enable us to draw the figures.

1. E and G are in the same vertical line; GE is the intensity of the pressure on $AC=\gamma y$.

2. Produce GF and UV to K. Then $GK=GU.\cot.a=H\tan.a.\cot.a=H$.

3. Produce EF and WV to I. Then $EI=EW\cot.a=T\tan.a.\cot.a=T=EF$.

It follows that the points E, F, G, K and I are independent of a. If those points are given in the case of the plane AB, they will be the same for any other.

4. The angles IFK and IVK are each 90°. Hence a circle can be drawn through I, F and K, which will contain all the points V, for every plane; IK is the diameter, and M the centre of the circle.

5. Draw VO parallel to FG. Then $VO=VU\cos.a=N\sec.a.\cos.a=N$.

6. Draw VP parallel to EF, to meet EW produced. Then $VP=VW\cos.a=S\sec.a.\cos.a=S$.

7. It follows from the above that if once the circle IFK be drawn, then in order to find the intensity of the pressure on any plane AB, we have only to draw IV parallel to AB and VO and VP are the normal and tangential intensities of stress on this plane.

Draw $HEWPML$ and HI. The latter is vertical. HV is the intensity of the stress on AB; the angle PHV is δ, or the angle that stress makes with the normal to AB.

8. As the plane AB is changed, or rotated about A, the point V moves around the circumference of the circle. The intensity of stress on AB has for its maximum value HL, on a plane parallel to IL and for its minimum value HN, on a plane parallel to IN. On these planes the stress is normal; hence these stresses are the "principal stresses." The planes IL and IN are at right angles. Hence *the planes on which the principal stresses act are at right angles to each other.*

9. The angle δ has its maximum value for a plane parallel to IR, HR being tangent to the circle; as well as for a second plane parallel to IQ, HQ being also tangent to the circle.

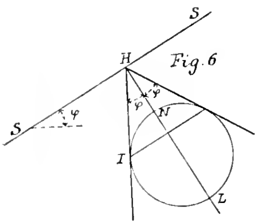
10. The line WU is parallel to the actual pressure on the plane AB.

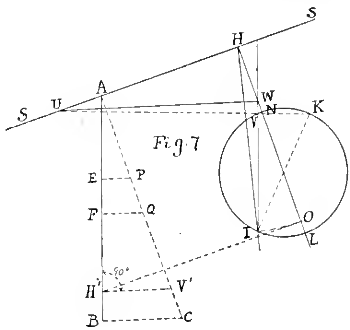
It is clear from the above that if once the circle is constructed, the

stress on any plane is easily found. It only remains to draw the circle.

This, however, we are unable to do in general, but we can locate it within limits. We know that the angle δ can never exceed the angle or friction φ, or angle of repose of the earth. Hence, if we draw from H two lines (Fig. 4) making angles φ on either side of $H E$, we know that the circle must be within those lines. Any circle through I, F, and K, which fulfills this condition is a possible circle of equilibrium, if we may so call a circle corresponding to a possible state of equilibrium of the mass of earth.

If the earth is just on the point of slipping, $\delta = \varphi$, and the circle is tangent to the two lines $H R$ and $H Q$ (Fig. 4). Two circles, $N_1 Q_1 L_1 R_1$ and $N_2 Q_2 L_2 R_2$ fulfill this condition, hence they represent the two limiting states of equilibrium when the earth is just ready to slip. It is with these cases only that the engineer has to deal. The larger





circle represents the case where the maximum principal pressure $H L$ (Fig. 3) is increased until the limiting condition is reached. This we may call the *passive* earth pressure; it occurs when a thrust or pressure, as of an arch or building, is exerted on the earth until it is just ready to give way. The smaller circle represents the case where the minimum principal pressure HN (Fig. 3) is decreased until the limiting condition is reached. This we may call the *active* earth pressure; it occurs when the thrust of a mass of earth is resisted, as by a retaining wall, and is, therefore, the most usual in the practice of the engineer. For the passive earth pressure the maximum pressure is $H L_2$ on a plane parallel to IL_2, and the minimum pressure HN_2 on a plane parallel to IN_2. For the active earth pressure the maximum pressure is HL_1, on a plane parallel to IL_1, and the minimum pressure HN_1 on a plane parallel to IN_1.

The maximum shear occurs on planes parallel to $I R_2$ and $I Q_2$ in the first case; $I R_1$ and $I Q_1$ in the second.

In the special case of a horizontal surface the force on AC is vertical, hence $E F = E I = o$, and the two circles are tangent. (Fig. 5). If the surface is inclined at the angle of repose φ, HQ is vertical, and coincides with $H I$, hence only a single condition of equilibrium is possible (Fig. 6).

In all the previous figures we have taken H in the line $S S$, which represents the surface. $I H$ is the intensity of the pressure on a plane parallel to the surface, hence it equals $\gamma\ y$. If the point considered is at a normal distance, IH, from the surface, then $y = IH$, and $\gamma\ y = \gamma . IH$. Hence IH represents a column of earth whose weight would produce the pressure really existing on a plane AC at a normal distance, $I H$, from the surface, and all the other lines in the figure which represent forces, such as $G U$, $U V$, etc., represent columns of earth which would produce the pressures they stand for, all for a point at a normal distance, $I H$, from the surface.

To find the total pressure on any plane.

The following constructions, which follow at once from the preceding paragraphs, are given by Mohr for finding the total pressure on any plane, such as the back of a retaining wall.

First Method. (Figure 7.)

The first step is to draw the circle $I L K$. This can easily be done geometrically, but the following method is simpler: Draw $S S$, representing the surface, and $H L$ perpendicular to it at any point H, making HL any convenient distance, say 5 inches; make

$$HN = HL . \tan.^2 \left(45^\circ - \frac{a}{2}\right)$$

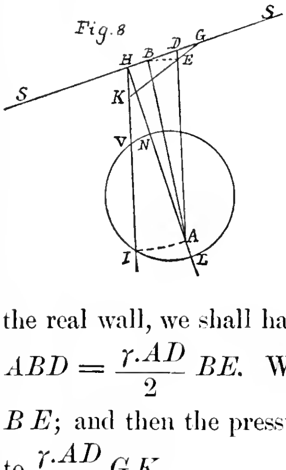
according to a formula yet to be explained. NL is the diameter of the circle. Draw HI vertically, the diameter IK, and a line IVW parallel to the wall: then draw KVU and UW, and the construction is complete. HV represents the intensity of the pressure at a point whose normal distance from the surface is $HI = HO$, and the pressure acts parallel to UW. No simpler construction could be desired. We have, then, if AB represents the wall, only to lay off HV at $H' V'$, perpendicular to AB, and knowing that the pressure is proportional to the depth below the surface, to draw the line $V'A$. The area of the triangle ACB, multiplied by γ, gives the pressure on the wall. If the

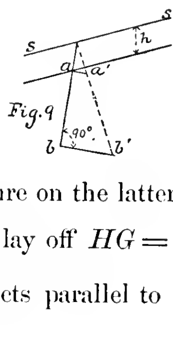
back of the wall is not plane, but composed of a number of planes, it is easy to find the pressure on each. Thus, in the above figure, the pressure on the part EF of the plane is represented by the area $EFPQ$. And finally, if the back is curved, we must divide it into a number of parts, and assume each to be plane. It is not necessary to go into farther details.

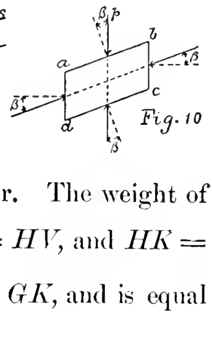
Second Method. (Figure 8.)

Draw the circle as before, and find first the pressure on a vertical plane. HV is the intensity of the pressure on such a plane at a point A, distant HI normally from the surface. If AD is the vertical plane the total pressure it supports is $\frac{\gamma . AD}{2} HV$, acting parallel to HD.

If we combine with this the weight of the triangle ABD, AB being







the real wall, we shall have the pressure on the latter. The weight of $ABD = \frac{\gamma . AD}{2} BE$. We, therefore, lay off $HG = HV$, and $HK = BE$; and then the pressure on AB acts parallel to GK, and is equal to $\frac{\gamma . AD}{2} GK$.

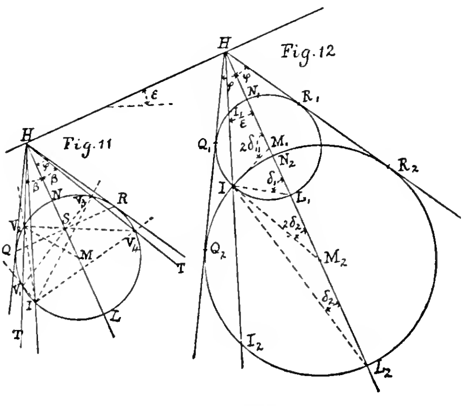
If the surface of the earth is loaded, reduce the load to the specific gravity of the earth, and let h be the height representing it (Fig. 9). The problem is, therefore, to find the pressure on a plane ab, as though the surface of the earth were $S'S'$. It will be represented by a trapezoid, $a\,a'\,b'\,b$.

That the pressure on a plane varies directly as the distance below the surface is easily seen when we remember that the pressure on a plane parallel to the surface follows that law, and that consequently the other pressures must do the some, inasmuch as Fig. 3 holds for any point, only the scale of forces changing. The resultant pressure

on a plane wall extending to the surface is, therefore, applied two-thirds of the distance from the top to the bottom.

Third Method. (Figure 10.)

This method depends upon the theorem of conjugate pressures; the pressure on a given plane ab having a certain direction, p, the pressure on a plane bc parallel to p is parallel to ab. (Fig. 10). The stresses on the four planes in Fig. 10 make, therefore, the same angle β with the normal. Now, if we draw (Fig. 11) the lines HT, HT', both making angles of β with HL, then the pressure on each of the four planes IV_1, IV_2, IV_3, IV_4, will make the angle β with the normal. The stress on IV_1 must be parallel to either IV_2, IV_3, or IV_4, and as the angle $V_1IV_3 = V_1V_4V_3 = 90° - \beta$, it is clear that it must be parallel to IV_3, so that IV_1 and IV_3, as well as IV_2 and IV_4, are a pair of conjugate planes. To find the direction of the stress on IV_1, then, it is only necessary to lay off the angle $LHT' = LHV_1$, and draw IV_3.



But it so happens that if we draw V_1V_3, crossing HL in S, we have the triangles HV_2M and HV_1S similar, and $HS : HV_1 :: HV_2 : HM$ ∴

$$HS = \frac{HV_1.HV_2}{HM} = \frac{\overline{HQ}^2}{HM},$$ so that S is the point when QR meets HL, and is, hence, independent of V_1. In order, then, to find the direction of the pressure on a plane IV_1, we need only to draw V_1SV_3, and IV_3 is the required direction.

The preceding method will by its simplicity and accuracy commend itself to all. Founded on the condition of equilibrium of a particle of earth, it ought to give results agreeing with the analytical theory first

given by Rankine. The following equations, which the reader will easily demonstrate, will show the complete agreement of the two.

$$\sin.\varphi = \frac{N_{\text{max.}} - N_{\text{min.}}}{N_{\text{max.}} + N_{\text{min.}}} \qquad (1)$$

$$\frac{1 - \sin.\varphi}{1 + \sin.\varphi} = \tan.^2\left(45^\circ - \frac{\varphi}{2}\right) = \frac{N_{\text{min.}}}{N_{\text{max.}}} \qquad (2)$$

Call δ the angle between the surface and the direction of N_{max}; then from the triangles HIM_1 and HIM_2. (Fig. 12.)

$$\frac{M_1 I}{M_1 H} = \sin.\varphi = \frac{\sin.\varepsilon}{\sin.(2\delta_1 + \varepsilon)} \qquad (3)$$

$$\frac{M_2 I}{M_2 H} = \sin.\varphi = \frac{\sin.\varepsilon}{\sin.(2\delta_2 + \varepsilon)} \qquad (4)$$

$$\sin.(2\delta + \varepsilon) = \frac{\sin.\varepsilon}{\sin.\varphi} \qquad (5)$$

$$\sin.2\delta = \frac{\sin.\varepsilon}{\sin.\varphi}\left[\cos.\varepsilon \pm \sqrt{\cos^2\varepsilon - \cos.^2\varphi}\right] \qquad (6)$$

Let y = normal distance from surface; then

$$HM_1 = \frac{1}{2}(N_{1\,\text{max.}} + N_{1\,\text{min.}}) = HI \,.\, \frac{\sin.(2\delta_1 + \varepsilon)}{\sin.2\delta_1}$$

$$= y \frac{\sin.(2\delta_1 + \varepsilon)}{\sin.2\delta_1} \qquad (7)$$

$$IM_1 = y \frac{\sin.\varepsilon}{\sin.2\delta_1} \qquad (8)$$

$$HM_2 = y \frac{\sin.(2\delta_2 + \varepsilon)}{\sin.2\delta_2} \qquad (9)$$

$$IM_2 = y \frac{\sin.\varepsilon}{\sin.2\delta_2} \qquad (10)$$

From (5), $(2\delta_1 + \varepsilon) + (2\delta_2 + \varepsilon) = 180^\circ$; $\delta_1 + \delta_2 = 90^\circ - \varepsilon$ (11)

In (6), one of the signs of the double signs must apply to δ_1 and the other to δ_2; one cannot apply to both, for then we might have $\sin.2\delta_1 = \sin.2\delta_2$ or $\delta_1 + \delta_2 = 90^\circ$, which is contradictory of (11). We have, then,

$$N_{1\text{max.}} = \gamma.HL_1 = \gamma.(HM_1 + IM_1) = \gamma y. \left[\frac{\sin.(2\delta_1 + \varepsilon)}{\sin.2\delta_1} + \frac{\sin.\varepsilon}{\sin.2\delta_1}\right]$$

$$= \gamma y \frac{1 + \sin.\varphi}{\cos.\varepsilon + \sqrt{\cos.^2\varepsilon - \cos.^2\varphi}}.$$

$$= \gamma y \frac{\cos.\varepsilon - \sqrt{\cos.^2\varepsilon - \cos.^2\varphi}}{1 - \sin.\varphi} \tag{12}$$

Similarly,

$$N_{1min.} = \gamma y \frac{1 - \sin.\varphi}{\cos.\varepsilon + \sqrt{\cos.^2\varepsilon - \cos.^2\varphi}} =$$

$$\gamma y \frac{\cos.\varepsilon - \sqrt{\cos.^2\varepsilon - \cos.^2\varphi}}{1 + \sin.\varphi} \tag{13}$$

$$N_{2max.} = \gamma y \frac{1 + \sin.\varphi}{\cos.\varepsilon - \sqrt{\cos.^2\varepsilon - \cos.^2\varphi}}$$

$$= \gamma y \frac{\cos.\varepsilon + \sqrt{\cos.^2\varepsilon - \cos.^2\varphi}}{1 - \sin.\varphi} \tag{14}$$

$$N_{2min.} = \gamma y \frac{1 - \sin.\varphi}{\cos.\varepsilon - \sqrt{\cos.^2\varepsilon - \cos.^2\varphi}}$$

$$= \gamma y \frac{\cos.\varepsilon + \sqrt{\cos.^2\varepsilon - \cos.^2\varphi}}{1 + \sin.\varphi} \tag{15}$$

The intensity of the pressure on a vertical plane is represented for the passive state by $H I_2 = p_2$, and for the active state by $H I_1 = p_1$, and we have

$$p_1 . H I = p_1 . \gamma . y = \overline{Q_1 H}^2 = N_{1max.} N_{1min.}$$

$$= \gamma^2 y^2 . \frac{\cos.\varepsilon - \sqrt{\cos.^2\varepsilon - \cos.^2\varphi}}{\cos.\varepsilon + \sqrt{\cos.^2\varepsilon - \cos.^2\varphi}}, \text{ hence}$$

$$p_1 = \gamma y \frac{\cos.\varepsilon - \sqrt{\cos.^2\varepsilon - \cos.^2\varphi}}{\cos.\varepsilon + \sqrt{\cos.^2\varepsilon - \cos.^2\varphi}} \tag{16}$$

Similarly,

$$p_2 = \gamma y \frac{\cos.\varepsilon + \sqrt{\cos.^2\varepsilon - \cos.^2\varphi}}{\cos.\varepsilon - \sqrt{\cos.^2\varepsilon - \cos.^2\varphi}} \tag{17}$$

These equations show the complete agreement of the two methods.

Mohr has shown how the influence of the cohesion of the earth may be taken into account, but as this has little practical importance it is not necessary to do more than allude to it.

Finally, a few words regarding the limits within which the theory or method is applicable. We have assumed a plane upper surface. For this case our results are absolutely exact, but if the top surface is not plane, it is generally conceded that an exact solution of the problem of finding the pressure on any plane is impossible. But even

with a plane upper surface, we have seen that on any plane except one parallel to the surface, there are various pressures which are compatible with equilibrium. We have shown how to find the pressures for the two limiting conditions, when the earth is just ready to slide; or, in other words, we have found for any plane the least and greatest pressures consistent with equilibrium. In applying the method, then, it is only necessary to be sure that we know just what case we have to do with. In the case of a retaining wall we wish to find how it must be proportioned in order to prevent the mass of earth from sliding, *i. e.*, we wish to find the least pressure which would hold the earth in equilibrium, and make our wall so that the pressure will not displace it. Now, although by the method given we can find the least pressure on any plane in an unlimited mass of earth, yet it is not on every plane that we can replace the pressures by the resistance of a wall. Suppose, for instance, we made a wall parallel to the surface, removing the earth above; this is entirely without meaning, for then there would be no earth above that plane, and the earth would stand without the wall. Other positions can readily be imagined, in which a wall could be placed without experiencing the pressure which would act on that plane in an unlimited mass of earth. The following limitation, given by Mohr, will now be readily seen to be reasonable:

"A mass of earth supported by a wall is in the active condition as regards pressure, or at the lower limit of equilibrium, and in order to determine the pressure on the wall, the theory of earth pressure in an unlimited mass of earth may be applied, provided that the straight line, which, according to that theory, gives the direction of the maximum principal stress, at the foot of the wall, lies within the mass of earth." In other cases, as, for instance, where the earth slopes downward from the wall, Mohr advocates the use of the old theory, so ably discussed in these pages not long ago by Prof. Du Bois, the pressure, however, being assumed perpendicular to the wall. Such cases, however, will not often occur in the practice of the engineer. In cases where the surface of the earth is not plane, the method can be used, and probably is as correct as any other, if the real surface be replaced by a plane. The engineer will readily see in each particular case how such a plane can best be assumed.

THE PLATINUM-WATER PYROMETER.

By J. C. Hoadley.

The following description of the apparatus used for the determination of high temperatures, up nearly to the melting-point of platinum, is offered in answer to several inquiries on the subject.

The object to be attained is a convenient and reasonably accurate application of the method of mixtures to the determination of temperatures above the range of mercurial thermometers, say 500°F., up to any point not above the melting-point of the most refractory metal available for the purpose, platinum.

A first requisite is a cup or vessel of convenient form, capable of holding a suitable quantity of water, say about two pounds avoidupois. Berthelot decidedly prefers a simple can of platinum, very thin, with a light cover of the same metal, to be fastened on by a bayonet hitch. For strictly laboratory work, this may be the best form; but for the hasty manipulation and rough usage of practical boiler testing something more robust, but, if possible, equally sensitive, is required. The vessel I have used is represented in section in the accompanying cut, Fig. 1.

The inner cell, or true containing vessel, is 4·25 inches in diameter, and of the same height on the side, with a bottom in the form of a spherical segment, of 4·25 inches radius. It is formed of sheet brass 0·01 inch thick, nickel-plated and polished outside and inside. The outer case is 8 inches diameter and 8·5 inches deep, of 16-ounce copper, nickel-plated and polished inside, but plain outside. There are two handles on opposite sides, for convenience of rapid manipulation. The top, of the same copper as the sides and bottom, is depressed conically, like a hopper, and wired at its outer edge, forming a lip all around for pouring out of. The central cell is connected with the outer case only by three rings of hard rubber (vulcanite), each 0·25 inch thick, the middle ring completely insulating the cell from its continuation upward, and from the outer case. A narrow flange is turned outward at the upper edge of the cell, and a similar flange is also turned outward at the lower edge of the cylindrical continuation of the walls of the cell upward. Between these two flanges, the

middle ring of hard rubber is interposed, and the two parts, the cell and its upward continuation, are clamped together by the upper and lower rings of hard rubber, which embrace the flanges and are held together by screws. The joints between the flanges and the middle ring of hard rubber, which might otherwise leak a little, are made tight with asphaltum varnish.

Fig. 1 shows two partitions, dividing the space between the cell and the case into three compartments, and a concave false bottom. The cover is also seen to be divided into three compartments, by two partitions, and each compartment of the vessel and of its cover is provided with a small tube for inserting a thermometer. This construction was adopted in the first instruments made, for the purpose

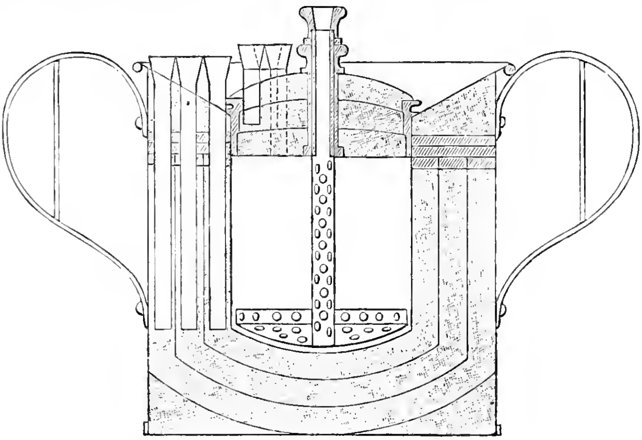


Fig. 1.

of observing the rate of heat transmission through the successive compartments, but these parts are without importance with respect to the practical use of the instrument, and may as well be omitted, as they considerably increase the cost, being nickel-plated and polished on both sides. The top and bottom plates of the cover are of 0·01 inch brass, nickel-plated and polished on both sides, both convex outward, the bottom plate but slightly, the top plate to 4·25 inches radius. A ring of hard rubber connects, yet separates and insulates these plates, and they are bound together with the ring into a firm structure by a tube of hard rubber, having a shoulder and knob at the top, and at the lower end a screw-thread engaging with a thin nut soldered to the upper-side of the bottom plate. When the cover is in place, its lower plate is even with the top of the cell; and the

contained water, which nearly fills the cell, is surrounded by polished, nickel-plated, brass-plates 0·01 inch thick, insulated from other metal by interposed hard rubber. The spaces between the cell and case (a single space if the partitions are omitted), the space above the hard rubber rings and the space or spaces in the cover are all filled with eider-down, which costs $1.00 per ounce avoidupois, but a few ounces are sufficient. Soft, fine shavings, or turnings of hard rubber are said to be excellent as a substitute for eider-down. Heat cannot be confined by any known method. Its transmission can be in some degree retarded, and in a greater degree, perhaps, regulated. Some heat will be promptly absorbed by the sides, bottom, and cover of the cell, and by the agitator; but this does no harm, as its quantity can be accurately ascertained and allowed for. Some will be gradually transmitted to the eider-down, filling the spaces, and through this to the outer casing; but this can be reduced to a minimum by rapid and skillful manipulation, and its quantity, under normal conditions, can be ascertained approximately, so as not to introduce large errors. But varying external influences, such as currents of air, caused by opening doors, or by persons passing along near the apparatus during the progress of an experiment, which would introduce disturbing irregularities, can best be guarded against by such spaces as I have described, filled with the poorest heat-conductor and the lightest *solid* substance attainable. Air, although a poor heat-conductor, and extremely light, is diathermous, and offers no obstruction to the escape of radiant heat.

The agitator is an important part of the apparatus. Its object, in this instrument, is two-fold. *First,* it serves to produce a uniform temperature throughout the body of water in the instrument; and *secondly,* it answers as a support to the heat-carrier of platinum or other metal, often intensely hot, which would injure or destroy the delicate metal of the bottom if allowed to fall on it. For this second purpose, no spiral revolving agitator, such as that commended by Berthelot, would suffice. The best form is such as I have shown in Fig. 1. A concave disc of sheet-brass, made to conform to the shape of the bottom of the cell, with a narrow rim turned up all around, of about 0·02 inch thickness, is liberally perforated with holes to lighten it, and to give free passage to water. The concave form causes the streams of water, produced by slightly raising and lowering the agitator, to take a radial direction downward or upward, so as to cross each other and promote rapid mixing. By a slight modification

small vanes might be turned outward from the surface of the metal, which would produce mixing currents if the agitator were given a slight reciprocatory revolving motion, thus avoiding the alternate withdrawal and re-immersion of any part of the stem so strongly deprecated by Berthelot; but for several reasons I think an up and down motion of the agitator desirable in this instrument. The platinum heat-carrier, sometimes at a temperature of 2500° to 2800°F., is thereby brought into more rapid and forcible contact with the water, steam or water in the spherical condition is washed away from its surface, and by cooling it more rapidly, the duration of the observation is lessened, and errors due to transmission of heat through the walls of the instrument are diminished. The upper part of the agitator stem is of hard rubber, and the brass portion, which terminates at the under side of the cover when the agitator is in its lowest position, suspended by the shoulder at the upper end, need never be lifted for the purpose of mixing out of the hard rubber tube at the cover, so that loss of heat from this cause must be very slight. The brass tube is very freely perforated with holes to admit water, streaming radially through the holes in the agitator, to contact with the thermometer. The hole in the stem at the top is flared, to receive a cork, through which the thermometer is to be passed. The bulb of the thermometer should be elongated, and very slightly smaller in diameter than the stem. After passing it through the cork, a very slight band—a mere thread—of elastic rubber should be put around the bulb, near its lower end, or a thin, narrow shaving of cork may be wound around and tied on, to keep it from contact with the brass tube, for safety; and a little tuft of wool, curled hair, or hard rubber shavings should be put in the bottom of the brass tube to avoid accidents. For the same purpose, a light, but sufficient fender of brass wire, say 0·03 inches diameter, might be judiciously placed around the brass tube at a little distance, to protect it and the thermometer inside of it from shocks from the platinum ball when hastily thrown in, as it must always be. I have had delicate and costly thermometers broken for want of such a fender. Thermometers cannot be too nice for this work. For accurate work at moderate temperatures, they should be about 14 inches long, having a "safe" bulb at the upper end, with a range of 20°F.—32° to 52°—in a length of 10 inches, giving half an inch to a degree F., and carefully graduated to tenths of a degree, so that they can be read to hundredths, corresponding to single degrees of the heat-carrier in the normal use of the instrument.

For the determination of the highest temperatures, up closely to 2900°F., it will be convenient to have thermometers of greater range, say 32° to 82°F., 50° in a length of 12·5 inches, or a quarter of an inch to a degree F., also graduated to tenths, or at the least, to fifths of a degree. Such thermometers will be about 17 inches long.

It is very satisfactory to have *two* instruments and a good outfit of thermometers and heat-carriers, in order to take duplicate observations for mutual verification and detection of errors.

Heat Carriers.

For these platinum is greatly to be preferred to any other known substance. Its rather high cost is the only objection to its use. Its heat capacity is low, by weight, but its specific gravity is great, and sufficient capacity can be obtained in moderate bulk, while its high conductivity tends to shorten the duration of each experiment or observation. A convenient outfit for each instrument consists of three balls, hammered to a spherical form, one 1·1385 inches diameter, weighing 4200 grains, = 0·6 pounds avoirdupois; one 0·9945 inch diameter, weighing 2800 grains, = 0·4 pounds; and one 0·7894 inch diameter, weighing 1400 grains, = 0·2 pounds.

These can be obtained at $1\frac{2}{3}$ cents per grain, and will cost, respectively, $70.00, $46.67, and $23.33, and collectively, $140.00. At the assumed specific heat of Pt = $0{\cdot}03\dot{3}\dot{3}$, the heat capacity of the respective balls will be $\frac{1}{100}$, $\frac{1}{150}$ and $\frac{1}{300}$ of 2 pounds of cold water, and the two smaller balls used together will be equal to the larger one. Corrections for varying specific heat of platinum may be conveniently made by the tables given in a previous article.* Corrections for varying specific heat of water are less important, but may be made by the following table:

A composite heat-carrier, of iron covered with platinum, answers well for temperatures up to about 1500°F. A ball of wrought iron 0·88 inch diameter will weigh 700 grains, and a capsule of platinum spun over it 0·048 inch thick, making the outside diameter $0{\cdot}97\dot{6}$ inch, will also weigh 700 grains. Upon the assumption of 0·0333 for the specific heat of Pt and $0{\cdot}166\dot{6}$ for that of Fe, the composite ball will have a heat capacity equal to that of 4200 grains of Pt, and equal to 0·01 of that of 2 pounds of cold water. A patch, about 0·35

* Journal for August, pp. 97, 98, and errata in Journal for September, p. 172.

Temperatures, Fahrenheit, and Corresponding Number of British Thermal Units Contained in Water from Zero Fahrenheit.

Deg	B. t. u.	Deg.	B. t. u.	Deg.	B. t. u.	Deg.	B. t. u.
32	32·000	57	57·007	82	82·039	107	107·101
33	33·000	58	58·007	83	83·041	108	108·104
34	34·000	59	59·008	84	84 043	109	109·107
35	35·000	60	60·009	85	85·045	110	110·110
36	36·000	61	61·010	86	86·047	111	111 113
37	37·000	62	62·011	87	87·049	112	112·117
38	38·000	63	63·012	88	88·051	113	113 121
39	39·001	64	64·013	89	89·053	114	114·125
40	40·001	65	65·014	90	90·055	115	115·129
41	41·001	66	66·015	91	91·057	116	116·133
42	42·001	67	67·016	92	92·059	117	117 137
43	43·001	68	68·018	93	93·061	118	118·141
44	44·002	69	69 019	94	94·063	119	119·145
45	45·002	70	70 020	95	95·065	120	120·149
46	46·002	71	71·021	96	96·068	121	121·153
47	47·002	72	72 023	97	97·071	122	122·157
48	48·003	73	73·024	98	98·074	123	123·161
49	49 003	74	74·036	99	99 077	124	124·165
50	50·003	75	75·027	100	100·080	125	125 169
51	51·004	76	76·029	101	101·083	126	126·173
52	52·004	77	77·030	102	102·086	127	127·177
53	53·005	78	78·032	103	103·089	128	128·182
54	54 005	79	79·034	104	104·092	129	129·187
55	55·006	80	80·036	105	105·095	130	130·192
56	56·006	81	81·037	106	106·098	131	131·197

inch diameter, has to be put in to close the orifice where the Pt capsule is spun together, and a slight stain will show itself at the joint around this patch, from oxidation of the iron, but the latter will be pretty effectually protected. Difference of expansion, which will not exceed ·007 inch in diameter, will not endanger the capsule of Pt. The interruption of conductivity at the surface contact of the two metals makes the process of heating and cooling a little slower, but not noticeably so.

Such composite balls can be obtained for $20 each, $50 less than the cost of an equivalent ball of solid platinum, which is preferable in all but cost. Iron balls could be used for a few crude determinations. Cast iron varies too much in composition, and wrought iron oxidizes rapidly. While the oxide adheres it gains in weight, and when scales fall off it loses; and the specific heat of the oxide differs from that of metallic iron. Whatever metal is used, care must be taken to apply the appropriate tabular correction for Pt, Fe, or Pt, and Fe.

Manipulation.

Small graphite crucibles with covers, as shown in section in Fig. 2, serve to guard against losing the ball, to handle it by when hot, and to protect it against loss of heat during transmission from the fire to the pyrometer. To guard against overturning the crucibles, moulded

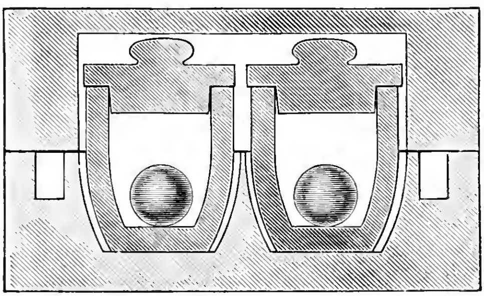


Fig. 2.

fire-brick should be provided to receive them,—two crucibles being put into one brick, in the same exposure, whenever great accuracy is desired, each serving as a check on the other, and their mean being likely to be more nearly correct than either one if they differ. The fire-brick cover is occasionally useful to retard cooling if, by reason of local obstructions, some little delay is unavoidable in transferring the

balls from the fire to the water of the pyrometer. With convenient arrangements this may be done in three seconds. After observing the temperature of the water, make ready for the immersion of the heat-carrier by raising the agitator until a space of only about 1·5 inch is left between its rim and the cover. An instant before putting in the heat-carrier—"pouring" it in from the crucible—lift the cover and agitator both together, so that the rim of the latter is level with the sloping top of the instrument. The agitator then receives the hot ball without shock, and no harm is done. If the ball goes below the agitator it is likely to injure the bottom of the cup. If, on taking the temperature of the water before the immersion of the heat-carrier, any change is observed, either rising or falling, the direction and rate of such change, and the exact interval of time between the last recorded observation and the immersion should be noted, in order to determine the exact temperature of the water at the instant of immersion. The temperature of the water will continue to rise as long as the heat-carrier gives out heat faster than the cell loses it. The rise will grow gradually slower until it ceases, and the maximum can be very accurately determined. Examples of the mode of using the tables, and of determining the true temperature of the heat-carrier at the instant of immersion from the observations with the instrument, are given in the table on pages 170 and 171 of this journal for September. A method of using the tables by which a closer approximation to the true temperature may be reached, will be pointed out in a subsequent article.

Determination of the calorific capacity of the metals of the pyrometer, in terms of water, *i.e.*, in British thermal units.

First. Weigh the cup, or cell, the lower plate of the cover and the metallic portion of the agitator, and compute their heat-capacity by the specific heat of the respective metals. Compute also the heat-capacity of the thermometer; or, if it be long, of so much of it as is found to share nearly the temperature of the immersed portion. The result will be a minimum,—indeed, in so small a vessel the inevitable loss by conduction and radiation will amount to more than one-third as much as the simple heat-capacity of the metals.* The total must be ascertained by an application of the method of mixture. Ascertain the temperature of the interior of the instrument simply; pour in

* In our case the heat-capacity, thermometer included, was ·0757; total, ·1053; radiation, etc., ·0296. Respectively, 71·9 per cent. and 28·1 per cent. of the total.

quickly but carefully a known quantity of water, say about 2 pounds, of known temperature, say about 100°F., and ascertain the temperature as soon after pouring as mixing can be properly performed. But a correction is necessary for loss of heat in the act of pouring. To ascertain the amount of this correction prepare a bath of tepid water, and bring all parts of the instrument—outside, inside and interior portions, together with the vessel to pour from—exactly to one common, carefully ascertained temperature. Now take 2 pounds of the water and pour it into the cell in the same manner as before. Exposure of so thin a stream on two surfaces to the air of the room will produce a certain degree of refrigeration in the water, which is supposed to be warmer than the air, say at about 160°F. This effect will be due to conduction, by contact with the air, to radiation, and to evaporation; and by so much the refrigeration observed in mixing is to be diminished.

Four experiments, carefully conducted, gave the following results:

Loss of temperature by pouring at 170°F., 0·81°, 0·86°, 1·00°, and 1·07°F.; mean, 0·935°F.

The following are values of the calorific capacity of my pyrometers, that is, of those parts of each which share directly the temperature of the inclosed water, including the thermometer to be used with the instrument, and the heat communicated to the eider-down and otherwise lost during an observation, expressed in decimals of a British thermal unit, or in decimals of a pound of cold water:

0·1048, 0·1052, 0·1077, 0·1008, 0·1028, and ·01104.

Mean,	0·1053 =	0 lb.	1 oz.	11 drms.
Add water,	1·8947 =	1 "	14 "	5 "
	2·0000 =	2 "	0 "	0 "

This was the value used. The instrument, being put on delicate coin scales and counterbalanced, weights equal to 1·8947 lbs. avoirdupois = 1 lb. 14 oz. 5 drms. were added to the counterbalancing weights, and cold water was poured in until the scales again balanced.

The pyrometer with its contained water was then just equal in heat-capacity, while the temperature was not above 38°F. to 2 pounds of cold water. The two instruments were sensibly alike, but were numbered No. 1 and No. 2, and at each observation the one used was noted.

The process of preparation and testing appears long and tedious, and

is indeed somewhat so; but the instruments once well made are durable, convenient in use, and with care reasonably accurate.

Compared with mercurial thermometers between 212° and 600°F., I believe them to be much more accurate, although less convenient.

For a range of temperatures from 212° to 900°F. they are certainly more trustworthy than anything save an air thermometer of suitable construction; and for all temperatures from 800° or 900° F. up nearly to the melting point of platinum they are without a rival, so far I know.

For some situations the ball can best be inserted in the fire or other situation where an observation is desired, and withdrawn for immersion by means of long, slender tongs, with jaws resembling bullet-moulds.

A word about the melting point of platinum. My balls certainly began to melt below 2950°F., but I am by no means sure that they do not contain any silver, although their specific gravity gives assurance that are at least nearly pure.

EXPERIMENTS ON THE FATIGUE OF SMALL SPRUCE BEAMS.

By F. E. Kidder, B.C.E.

[Presented to the American Academy of Arts and Sciences by Prof. Chas R. Cross, May 10, 1882.

The following experiments were undertaken with the object of determining, if possible, what part of the so-called breaking load of a beam would ultimately cause the beam to break, all the conditions being the most favorable.

Incidental to the experiments the modulii of rupture and of elasticity of small beams of kiln-dried spruce were determined.

The experiments were made in the physical laboratory of the Massachusetts Institute of Technology, the testing machine used being the same as that described in a paper presented to the society, February 9, 1881, [also published in the Journal of the Franklin Institute, April, 1881]. With this machine the loads are applied by suspending known weights directly from the centre of the beam. The deflections of the beams were measured by means of a micrometer screw, the principle

of electrical contact being taken advantage of in reading it. Although the micrometer screw used was graduated so as to read to $\frac{1}{10000}$ of an inch, the writer doubted reliability beyond $\frac{1}{1000}$ of an inch, and the modulii given have been computed from deflections measured only to thousandths of an inch.

As the load was suspended from a bolt resting upon the beam at the centre, it was necessary to measure the deflections one inch from the centre. For the small deflections from which the modulii of elasticity were determined the difference between the measured deflection and the actual deflection is so small that it would not come within the limit to which the deflection was measured. For the deflections given in the tables the deflection at the centre would be somewhat larger, but the error does not practically affect the results.

As the room in which these experiments were made is kept very warm and dry, any unseasoned timber would be so affected by the heat that it would be impossible to tell whether the deflections were caused entirely by the load, or partly by the heat in the room; hence it was thought best in making these experiments to use kiln dried lumber.

The small beams upon which the experiments were made were taken from two spruce plank, selected from lumber which had been cut in Maine the previous season. The plank were kept in a drying kiln three weeks, and were then cut up into pieces about two inches square, and allowed to dry in the laboratory until tested.

For convenience the beams cut from one plank are classed as series No. 2, and those from the other as Series No. 3. Series No. 1 including those beams previously experimented upon, and which were discussed in my previous paper.

All of the pieces of wood experimented upon were what might almost be called perfect pieces, being straight grained and free from knots. They were about $1\frac{1}{2}$ inches square, and 40 inches between supports. The exact dimensions with other data being shown in the tables. Tables I, II and III are so arranged that a comparison of the strength and stiffness, together with the ultimate deflection of pieces in the different series can easily be made.

The letter E is used to denote the modulus of elasticity in these tables, and R the modulus of rupture. The quantity denoted by A is one-eighteenth of the modulus of rupture.

It will be noted that the pieces in Series No. 1, were not kiln-dried, but were taken from a plank, selected from ordinary lumber.

Table No. I.

Series No. 1.—*Unseasoned Spruce.*

No. of test piece	Clear span. l.	Breadth. B.	Depth. D.	E.	R.	Centre breaking w't for beam 1″×1″×1′. A.	Deflection just before breaking.
	ins.	ins.	ins.	lbs.	lbs.	lbs.	ins.
1	40	1·475	1·45	1,731,000	11,380	632	1·565
2	40	1·445	1.52	1,556,000	10,330	574	1·394
3	40	1·469	1·448	1,765,000	10,710	595	1·48*
4	40	1·42	1·498	1,736,000	10,830	601	1·466
5	40	1·45	1·485	1,688,000	11,980	665	1·579
6	40	1·48	1·44	1,795,000	11,040	613	....
7	40	1·464	1·46	1,682,000	10,570	587	....
8	40	1·42	1·48	1,647,000	11,280	626	1·571
9	40	1·46	1·46	1,704,000	11,180	621	1·425
10	40	1·441	1.46	1,616,000	12,440	691	1·81*

*Approximately.

Average value of E, 1,692,000 lbs.

Average value of R, 12,170 lbs.; of A, 620 lbs.

Series No. 2.

In commencing this series of experiments five of the beams were subjected to loads of 30 and 40 lbs., and the deflection measured at the end of one hour from the time the load was applied. From these deflections the modulii of elasticity have been calculated. The values

given in Table II are the average of the values obtained from the deflection under 30 lbs. and the deflection under 40 lbs.

Having determined the modulii of elasticity of these pieces, five pieces of the series were broken by means of a gradually increasing load, and from their breaking load the modulus of rupture of each

Table II.

Series No. 2.—*Kiln-dried Spruce.*

No. of test piece.	Clear span. *l.*	Breadth. *B.*	Depth. *D.*	*E.*	Deflection just before breaking.	*R.*	Centre breaking w't, for beam. 1″×1″×1′. *A.*
	ins.	ins.	ins.	lbs.	ins.	lbs.	lbs.
1	40	1·52	1·52	1,573,800	1·676	12,560	698
2	40	1·495	1·50	....	1·656	13,590	755
3	40	1·520	1·50	....	1·517	12,540	697
4	40	1·51	1·503	....	1·816	13,720	762
5	40	1·506	1·506	....	1·662	13,740	763
6	40	1·51	1·516	1,760,000	1·937	broke under $\frac{3}{4}$ B. W.	
7	40	1·508	1·508	1,636,000	1·79	" " $\frac{2}{3}$ B. W.	
8	40	1·510	1·518	1,721,000	....	car'd $\frac{2}{3}$ B.W. 22 d'ys.	
9	40	1·50	1·504	1,580,000	....	tested with $\frac{1}{2}$ B. W.	

Average value of *E* for five pieces, 1,654,000 lbs.
Average value of *R* for five pieces, 13,230 lbs.
Average value of *A* for five pieces, 735 lbs.

piece was computed. The average value of these five pieces (Nos. 1–5) was then considered to be the average value for the whole series, and the breaking weights of the remaining pieces of the series were computed on this basis.

Before attempting to break the remaining pieces, a load of 50

lbs. about $\frac{1}{15}$ of its breaking load, was applied to Piece No. 6, with the object of determining if the deflection under this slight load would continually increase. The load was kept on the beam 288 hours, and the deflections, taken at intervals, are given in Table IV. The

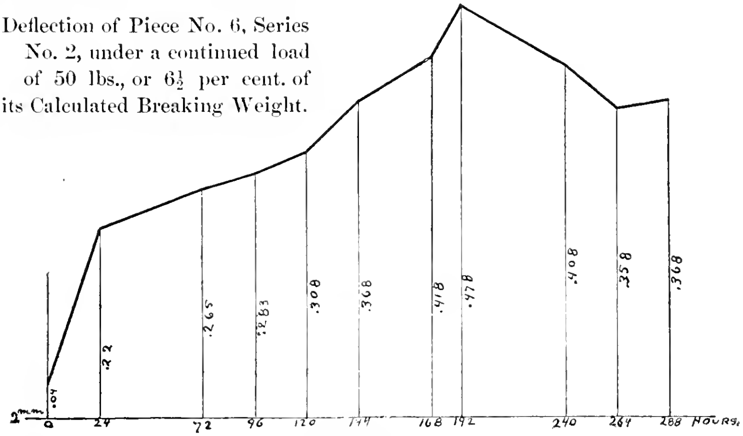


PLATE I.

increase in the deflection is also shown graphically by the diagram in Plate I. From these it will be seen that the deflection increased very rapidly for the first 24 hours, and then quite regularly, but slowly, for

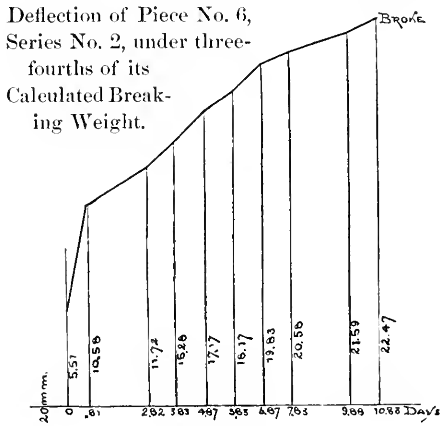


PLATE II.

192 hours, and after that it continued to *decrease* for 72 hours, when it slightly increased again. As it was desired to use the machine for the more direct purposes of the experiments, the piece was removed

from the machine, but it would have been interesting to have watched the further action of the load on the beam.

During the time that the deflections *decreased* the weather was very wet, and it is the opinion of the writer that the deflections were somewhat affected by the change in the condition of the atmosphere. It should be observed that the greatest increase of deflection was very small, being only 0·44 of a millimetre, or about ·017 of an inch.

TABLE No. III.—*Kiln-dried Spruce.*

No. of test piece.	Clear span. l	Breadth. B.	Depth. D.	Deflection just before breaking.	R.	Centre breaking w't for beam 1″×1″×1. A.
	ins.	ins.	ins.	ins.	lbs.	lbs.
1	40	1·54	1·534	1·59	10,500	583
2	40	1·54	1·54	1·654	10,596	588
3	40	1·545	1·54	1.638	10,644	591
4	40	1·54	1·545	1·42	8,487	471
5	40	1·54	1·54	1·575	9,200	511
6	40	1·54	1·532	1·607	broke under $\frac{3}{4}$ B. W.	
7	40	1·54	1·54	1·567	broke under $\frac{2}{3}$ B. W.	
8	40	1·541	1.541	....	tested with $\frac{1}{2}$ B. W.	

Average value of R, for five pieces, 9,885 lbs.
Average value of A, for five pieces, 549 lbs.

After allowing this same beam several days in which to recover from the strain caused by the load of 50 lbs., 574 lbs. or $\frac{3}{4}$ of its calculated breaking load was suspended from the beam and the deflection measured at frequent intervals, with the results shown in Table IV. After carrying the load 260 hours the beam broke. The dia-

gram on Plate 2 gives a graphical representation of the increase of the deflection.

Piece No. 7 of this series was computed to hold 756 lbs. before breaking, and 504 lbs. or ⅔ of the breaking weight was suspended

TABLE IV.—*Deflections of Piece No. 6, Series No. 2, under a Continued Load.*

Load of 50 lbs.—6½ per cent. of Breaking Weight.

Time applied.	Deflection.	Time applied.	Deflection.	Time applied.	Deflection.
hours.	mm.	hours.	mm.	hours.	mm.
0	2·04	120	2·308	240	2·408
24	2·22	144	2·368	264	2·358
72	2·265	168	2·418	288	2·368
96	2·283	192	2·478	load removed.	

Load of 574 lbs. or three-fourths of Calculated Breaking Weight.

Time applied.	Deflection.	Time applied.	Deflection.	Time applied.	Deflection.
hours.	mm.	hours.	mm.	hours.	mm.
0	25·51	69	33·83	140	38·17
1·5	28·72	75	34·33	165	39·83
4·5	30·58	92	35·28	188	40·58
1·95	31·72	117	37·17	237	41·59
				260*	42·47

* Broke shortly after.

from the beam. After supporting this load 134 hours the beam broke. The deflections of the beam, measured at frequent intervals, are given in Table V.

TABLE V.—*Deflection of Piece No. 7, Series No. 2, under 504 lbs., or two-thirds of its Calculated Breaking Weight.*

Time applied.	Deflection.	Time applied.	Deflection	Time applied.	Deflection.
hours.	mm.	hours.	mm.	hours.	mm.
0	23·04	48	34·43	110	41·64
14	28·48	86	38·06	120	43·16
24	31·26	96	40·04	134	45·46
38	33·16	....	....	broke soon after.	

Piece No. 8 of this series carried two-thirds of its breaking weight 499 hours, with an increase in deflection of 7·64 millimetres (·3 inch). As the deflection was constantly increasing, and was already more than the deflection of Piece No. 7 when the load was first applied, it seems to the writer that the beam would undoubtedly in time have been broken by its load The deflection of this beam is given in Table VI.

The last piece in Series No. 2, Piece No. 9, was subjected to a load of one-half of its breaking weight for 327 hours, during which time the deflection constantly increased from 16·39 mm. (0·644 in.) to 19·07 mm. (0·75 in.). The load was then removed and the "set" of the beam measured. This set gradually decreased as the beam recovered itself, until it was quite small, and probably the larger part of it was due to the indentation of the beam at the points of support, something which cannot well be prevented in a wooden beam.

After 21 days rest, the beam was put in the machine and the same load of 374 lbs., or one-half the breaking load, was alternately applied and taken off with the results shown in the last part of Table VII. It will be seen from this table that each time the load was applied the beam deflected a little more than at the previous application of

the load; also, that the set increased much faster than the deflection. This tends to prove that the continued application and removal of one-half the breaking weight of a beam will in a comparatively short time cause it to break.

TABLE VI.—*Deflection of Piece No. 8, Series No. 2, under 511 lbs. or two-thirds of its Calculated Breaking Weight.*

Time applied.	Deflection.	Time applied.	Deflection.	Time applied.	Deflection.
hours.	mm.	hours.	mm.	hours.	mm.
0	21·98	211	26·86	379	29·02
44	23·09	235	27·09	403	49·15
68	25·45	259	27·82	427	29·37
92	25·78	283	28·14	451	29·48
116	25·94	308	28·53	475	29·53
140	26·20	332	28·81	499	29·62
168	26·43	....	....	weight taken off.	

SERIES NO. 3.

The results of the second series of experiments convinced the writer that a perfect, dry spruce beam would in time break under a load of only one-half of its calculated breaking weight, but to make the results more certain, a third series was undertaken, with the same object in view. The pieces of wood tested in this series were to all appearances equally as perfect (and they must have been as dry) as those in Series No. 2.

Table III gives the dimensions of the beams in this series, the modulii of rupture of the first five pieces and the ultimate deflection of all of the pieces.

The average value of the modulii of rupture of the five pieces was

taken as the basis from which the breaking weight of pieces No. 6, 7 and 8 were computed.

Piece No. 6 of this series was broken by a load of three-fourths of its calculated breaking weight 22 days after the load was applied. The deflections of this beam at various intervals during the 22 days are given in Table VIII, and the increase in the deflection is shown graphically by the diagram on Plate 3.

TABLE VII.—*Experiments on Piece No. 9, Series No. 2.*

Deflection under 374 lbs., or one-half of its Calculated Breaking Weight.

Time applied.	Deflection.	Time applied.	Deflection.	Time applied.	Deflection.
hours	mm.	hours.	mm.	hours.	mm.
0	16·39	48	17·96	211	18·74
2	17·08	66	18·08	234	18·87
18	17·49	116	18·17	279	18·91
25	17·77	138	18·34	303	19·01
42	17·865	164	18·43	327*	19·07

*Load removed.

Recovery of the piece on removal of the above load after 327 hours' application.

Time to recover.	Set.	Time to recover.	Set.	Time to recover.	Set.
hours.	mm.	hours.	mm.	hours.	mm.
0	2·41	8	1·73	48	1·32
2	1.94	24	1·46	74	1·30*
4	1·74	32	1·38	....	....

*At least ·5 mm. of this set was due to the indentation of the beam at the points of support.

The next piece of the series, No. 7, was subjected to a load of two-

After 21 days' rest, the beam was again put in the machine, and the same load of 374 lbs. was alternately applied, and taken off with the following results:

Weight.	Deflection on application of load.	Time applied.	Deflection.	Set.	Time to recover.	Set.
lbs.	mm.	hours.	mm.	mm.	hours.	mm.
374	16·62	26	18·22	1·45	16	·53
"	17·34	8	18·54	1·60	15	·66
"	17·52	4½	18·49	1·70	15½	·67
"	17·75	9½	18·83	1·90	14½	·97
"	17·95	9½	19.00	1·97	14½	1·08
"	18·10	48	19·56	2·68	24	1·48
"	18·38	9½	19·52	2·50	14½	1·47
"	18·38	9½	19·48	2·40	14½	1·53
"	18·58	9	19·73	2·60	15	1·54
"	18·70	48	20·35	3·15	9	1·67
"	19·15	24	20·86	3:40	15	1·75
"	19·55	24	22·02	4·30	24	2·26
"	20·12	24	21·86	4·20	9	3·97
"	21·85	756	26·80	7·70	24	5·61
"	24·90	105	27·16	7·40	24	5·70

NOTE.—The numbers in column 5 show the set of the beam immediately after the removal of the load, which was suspended from the beam the number of hours given in column 3.

thirds of its breaking weight, which it carried 24½ days, and then gave way as the others had done.

The increase in the deflection of this beam was quite regular, as is shown by the diagram on Plate 4. The deflections are given in Table IX.

Deflection of Piece No. 6, Series No. 3, under three-fourths of its Calculated Breaking Weight.

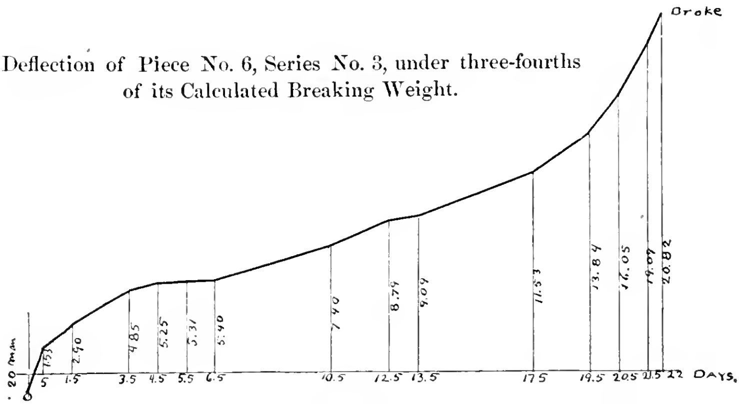


PLATE III.

Having proved that two-thirds of the so-called breaking weight of a beam is more than it will carry permanently, the next beam was subjected to only one-half of its calculated breaking weight.

This load was kept on the beam 49 days, during which time the

Deflection of Piece No. 7, Series No. 3, under two-thirds of its Calculated Breaking Weight.

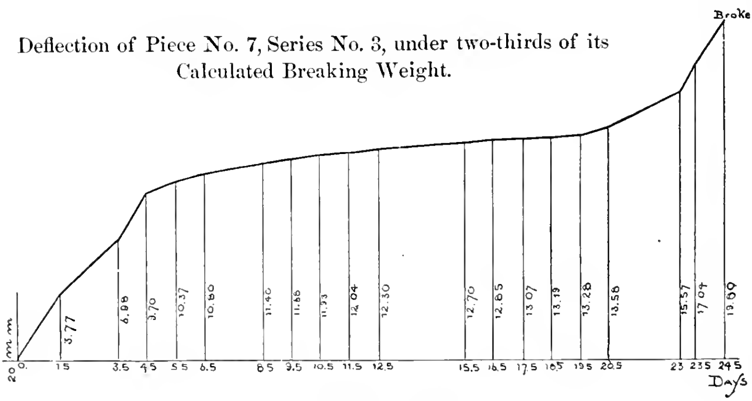


PLATE IV.

deflection increased from 13·4 mm. (0·527 in.) to 18·55 mm. (0·73 in.)

It was then necessary to remove the beam from the machine that

TABLE VIII.—*Deflection of Piece No. 6, Series No. 3, under a load of 399 lbs., or three-fourths of its Calculated Breaking Weight.*

Time applied.	Deflection.	Time applied.	Deflection.	Time applied.	Deflection.
days.	mm.	days.	mm.	days.	mm.
0	19·12	5·5	25·31	17·5	31·53
0·5	21·53	6·5	25·40	19·5	33·84
1·5	22·90	10·5	27·40	20·5	36·05
3·5	24·85	12·5	28·79	21·5	39·09
4·5	25·25	13·5	29·09	22	*40·82

* Broke within 12 hours.

TABLE IX.—*Deflection of Piece No. 7, Series No. 3, under a load of 401 lbs., or two-thirds of its Calculated Breaking Weight.*

Time applied.	Deflection.	Time applied.	Deflection.	Time applied.	Deflection.
days.	mm.	days.	mm.	days.	mm.
0	20·07	9·5	31·68	18·5	33·19
1·5	23·77	10·5	31·93	19·5	35·28
3·5	26·98	11·5	32·04	20·5	33·58
4·5	29·70	12·5	32·30	23	35·57
5·5	30·37	12·5	32·70	23·5	37·04
6·5	30·80	15·5	32·85	24·5	*39·80
7·5	31·40	16·5	33·07		

* Broke within 12 hours.

the latter might be used for other tests. The "set" of the beam on the removal of the load was 4·35 mm. (0·171 in.)

Seven days after the load was removed it was again put on the beam and allowed to remain 77 days, when it was again removed that the beam might be put on a temporary frame and kept there, with the same load suspended from it, until it broke.

The "set" of the beam on the second removal was only 3·76 mm. (0·148 in.), being less than what it was after the first removal.

The deflections of the beam are given in Table X, and the diagram on Plate No. 5 shows the increase in the deflection for both applications of the load. The upper line denotes the deflections under the second application of the load.

TABLE X.—*Deflection of Piece No. 8, Series No. 3, under a load of 301 lbs., or one-half of its Calculated Breaking Weight.*

Time applied.	Deflection.	Time applied.	Deflection.	Time applied.	Deflection.
days.	mm.	days.	mm.	days.	mm.
0	13·40	14	16·77	25	17·14
1	14·03	15	16·93	26	17·17
3	15·51	17	16·89	27	17·41
4	15·58	18	16·89	29	17·51
6	16·34	19	16·97	31	17·59
8	16·52	20	17·07	33	17·76
10	16·53	21	17·14	38	17·97
11	16·66	22	17·14	45	18.45
12	16·83	24	17·10	49*	18·55
13	16·79				

* After taking the last deflection the load was removed from the beam, when the centre of the beam returned to within 4·35 mm. of its original position.

After seven days, the load of 301 lbs. was again put on the beam and allowed to remain, causing the following deflections:

TABLE X.—(*Continued.*)

Time applied.	Deflection.	Time applied.	Deflection.	Time applied.	Deflection.
days.	mm.	days.	mm.	days.	mm.
0	13·20	23	15·70	59	16·84
1	14·25	38	16·18	63	16·95
3	14·61	43	16·43	66	17·05
5	14·90	47	16·50	68	17·11
10	15·25	48	16·52	71	17·15
13	15·37	53	16·64	77	17·32
18	15·73	54	16·70	load removed, set 3·76 mm.	

As this beam continued constantly to deflect, and as this increase in deflection is still going on, it seems to the writer that it must ultimately break under this load, for when the deflection reaches a certain

Deflection of Piece No. 8, Series No. 3, under a load of 301 lbs., or one-half of its Calculated Breaking Weight.

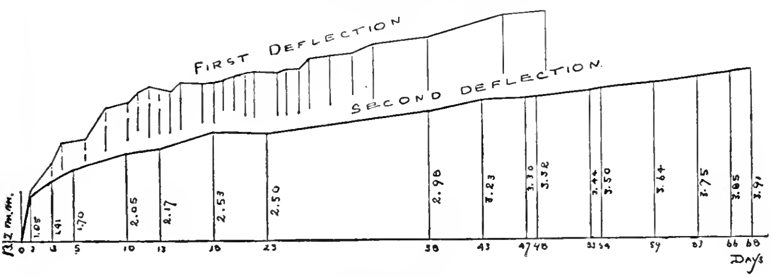


PLATE V.

limit it will, as is shown by the other pieces, rapidly increase until it breaks.

Observations on Tables I, II, and III.

Comparing Tables II and III we find a great difference in the values of the modulii of rupture for the two sets of experiments, although the planks from which the pieces were cut were selected from the same lot of lumber and dried the same length of time. The only reason which the writer can give for the low value of R in the 3d series is that the plank was sawn from the outside of the tree. It will be noticed that the values of R ran very high for the pieces in Series No 2, also that the average value of R for Series No. 1 is only about 8 per cent. less than that for Series No. 2, while it is about 23 per cent. greater than the average for Series No. 3. This would lead one to infer that ordinarily dry lumber does not have its strength materially increased by being kiln-dried.

Comparing Tables I and II we see that the average value of the modulus of elasticity for the beams of unseasoned spruce is fully as large as that for the kiln-dried spruce. The beams in Table I, though denoted as unseasoned, were fully as dry as timber which has been in an ordinary building three months, but it was not artificially dried.

If we compare the ultimate deflections of all the pieces with their modulus of rupture we shall find as a rule that those beams which were the strongest bent the most before breaking.

[The values of E in the Tables I, II and III were computed from the expression $E = \frac{W l_3}{4 \Delta B D_3}$, Δ denoting the deflection in inches. The values of R were computed from the formula $R = \frac{3}{2} \frac{W l}{B D_2}$]

From further observations of the tables we shall see that the deflections of Pieces Nos. 6 and 7 of Series No. 3 increased 100 per cent., or the deflection when the load was applied was only about one-half what it was when the beam broke.

Also that the deflection of Piece No. 9, Series No. 2, and of Piece No. 8, Series No. 3, is much less than one-half of what the ultimate deflection of the beam would probably be.

Hence I think it perfectly safe to conclude that for spruce beams of small sections a load which will produce a deflection of one-half of the maximum deflection of the beam before breaking will ultimately break the beam.

From a study of Tables VII and X it would appear that a load of one-half the so-called breaking load of a beam does not injure the beam when applied only for a short time; for it will be noticed that for both, Piece No. 9, Series No. 2, and Piece No. 8, Series No. 3, the deflection of the beam upon the second application of the load was almost the same as upon the first application, the difference being slight indeed.

Furthermore, it will be seen from the diagram on Plate No. 5 that the deflections of Piece No. 8 were greater on the first application than on the second, although the increase in deflection was in about the same proportion.

From an examination of the diagrams it will be seen that for the

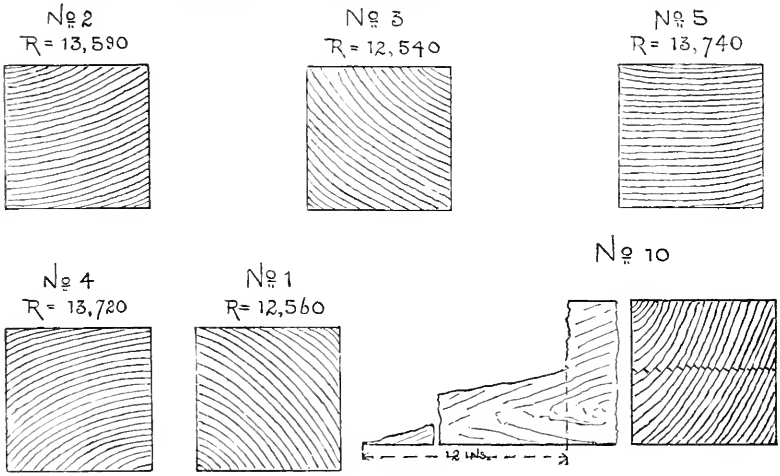


PLATE VI.

first twelve or twenty-four hours after the load is applied the deflection rapidly increases, and that from that time until about two or three days before the breaking the increase in the deflection is generally very regular, increasing again very rapidly as it nears the breaking point.

Effect of the "annual rings" on the strength of a beam.—After computing the modulii of rupture for the first five pieces of Series No. 2 the writer was surprised to see that three pieces had nearly the same modulus, and that the remaining two pieces also agreed almost exactly, but that there was a great difference between the modulii of the three and of the two pieces.

The writer could think of no reason for this phenomenon until

examining the fractured section of the beams, when it was discovered that in the three beams which had the high modulii the "annual rings" were parallel or nearly so with the top and bottom surfaces of the beam, while in the other two the "annual rings" made an angle of about 45° with these surfaces.

The figures on Plate 6 show the angle which the "rings" made with the top and bottom surfaces, and also the value of the modulus of each piece. Piece No. 10 was cross-grained, and as it broke under a very light load and by "slivering," it was thrown out from the series and is not given in the tables. The row of short lines across the centre of the section of this beem shows the manner in which the rings were broken—at right angles to their surface. We think that this plate shows very plainly the effect which the "annual rings" have upon the strength of spruce beams of small sections.

Conclusions.—The conclusions which may be drawn from the research here described the writer considers to be as follows: That for spruce beams of small section selected from lumber which has been moderately well seasoned and dried, the strength is not materially increased by the timber being kiln dried; that the modulus of elasticity is not proportional to the modulus of rupture and that the elasticity is not increased by kiln-drying the timber.

That with small spruce beams those which have the greatest strength bend the most before breaking.

That when a load between $\frac{1}{2}$ and $\frac{7}{8}$ of the so-called breaking weight is applied to a small spruce beam it produces a deflection which for a few few hours rapidly increases until the beam has fairly settled under its load; from this time the deflection increases gradually until a short time before breaking, when it increases more and more rapidly.

That a load of one-half of the so-called breaking weight if applied but for a few days does not injure such beams.

That a load which will cause such a beam to deflect one-half of its maximum deflection before breaking will ultimately break the beam.

That under the most perfect conditions small spruce beams will not permanently support a load of one-half their so-called breaking weight.

That the position of the annular rings in spruce beams of small section materially affects the strength of the beams, their strength being the least when the rings make an angle of 45° with the top and bottom surfaces of the beam.

The writer agrees with Prof. R. H. Thurston in considerlng 5 as

the least factor of safety which should be used for wooden beams under an absolutely static load.

In conducting this investigation the writer has received much assistance and encouragement from Mr. Silas W. Holman, of the Institute of Technology.

Boston, Mass., April 9, 1882.

THEORY OF THE STEREOSCOPE.*

By W. Le Conte Stevens.

Sun-painting and sun-sculpture are names that have been applied to the products of two sciences which have grown up together during the latter half of the present century. The chemistry of light has given us the art of photography; the study of twin photographs has enlarged our knowledge of the physiology of vision; chemical optics and physiological optics have thus been developed together. A single photograph, viewed with a single eye, may present the perspective illusion of the painter's art; a pair of photographs, properly taken, and properly viewed with a pair of eyes, presents an illusion that the painter may seek but the sculptor only can fully attain.

The camera and the stereoscope are no longer novelties; but the theory of the latter instrument, advanced by the physicist who invented the form most generally in use, and currently taught since his time, cannot be accepted to-day. The writer is aware that, in consenting to present a *résumé* of some recent investigations on this subject, he may be giving to the readers of this journal what some of them have already seen expanded by him elsewhere; if so, no claim can be made to a renewal of their attention.

Before criticising any theory currently taught, it may be well to state it clearly. It has long been known that the judgment of locality is more accurate when two eyes are used than in monocular vision. Kepler† in 1604 stated that the distance between the two eyes is a base-line which we employ in estimating the distance of a point by a species of visual triangulation. After the invention of the stereoscope by Wheatstone in 1838, Kepler's principle was applied to the deter-

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* The following summary of the author's investigations was prepared for the JOURNAL by special request.—W. H. W.

† Paralipomena, pp. 62–66, 1604.

mination of the apparent position of the object viewed, rays from the twin pictures being reflected into the observer's eyes, as if coming from a single object in front. The refracting stereoscope, devised by Brewster in 1849, shortly before improvements in photography made it easy to multiply stereographs at will, soon became popular; and the theory of visual triangulation at once found its way into our text-books in physics, where it may still be seen. The diagram generally employed is that of Fig. 1, or its equivalent. The construction of the stereograph being explained, it becomes obvious that the distance between corresponding background points on the twin pictures must exceed that for the foreground. Let aa' be the foreground interval, bb' that for the background; the lenticular prisms being interposed between the stereograph and the eyes, R and L. Then by refraction a and a' appear combined at A, b and b' at B. The two visual lines form with the interocular base line, RL, an isosceles optic triangle,

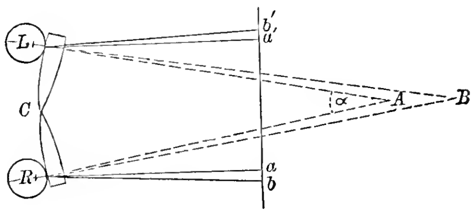

Fig. 1.

whose angle at the vertex, α, can be measured. Let i = base line RL; then for the distance, D, of the vertex, A, from either eye, we have, $D = \frac{1}{2}\, i \,.\, \text{cosec.}\, \frac{1}{2}\, \alpha$.

From this equation it is obvious that if such a relation can exist between the stereograph, the lenticular prisms, and the eyes of the the observer, as to make the visual lines parallel or divergent in order to retain single vision, the formula brings a result that is physically impossible. If its generality be thus disproved, it becomes interesting to inquire whether it is really applicable when the optic angle, α, is positive, and if not, whether there is any basis for such a theory of stereoscopic perspective as has been current for forty years.*

Most persons find it not easy to direct the eyes in a manner different from that which the ordinary necessities of vision have made habitual. The power to do so can be acquired by the exercise of a little perse-

* Wheatstone, Physiology of Vision, Phil. Trans., part ii, 1838. Brewster, The Stereoscope, pp. 50–100, 1856. Ruete, Das Stereoscop, p. 46, 1860.

verence, but to obviate the necessity of this, refracting glasses in the stereoscope are commonly employed. If without these a screen be used to hide each picture of the stereograph from the eye on the side opposite, and thus remove the temptation to converge the visual lines to the same external point, each eye looks at the picture immediately in front, and it is easy thus to secure single binocular vision. If the interval between corresponding points on the stereograph equal or exceed that between the observer's optic centres, there can be no meeting of visual lines in front. The writer has often thus secured stereoscopic effects without using the stereoscope, and without employing any screen, when conditions were such as to necessitate 4° or 5° of optic divergence. Indeed this relation between the visual lines is by no means uncommon in using the stereoscope. It implies uncomfortable strain upon the external rectus muscles by which the eyeballs are rotated outward. Probably few persons have ever used this instrument without experiencing discomfort at times.

In 1861 a German physiologist, Burckhardt,* called attention to the fact that similar pictures could be binocularly combined with slight optic divergence. The same observation was independently made during the following year by Professor C. F. Himes,† now of Carlisle, Pa., who published a paper on the subject in the *American Journal of Photography*, and subsequently contributed a series of papers on binocular vision to the JOURNAL OF THE FRANKLIN INSTITUTE. Helmholtz also refers to stereoscopy by the same method, but makes no provision for it in his mathematical discussion of the stereoscope. Despite these publications, the theory of visual triangulation is still generally reproduced in our text-books.‡ So far as the writer is aware, no analysis of vision by optic divergence has been made until recently, although its possibility has long been known.

If mathematics be applied to the theory of the stereoscope it must be restricted to the preparation of the stereograph, in which account must be taken of all the laws of mathematical perspective. So far as we can explain the illusion produced in binocularly regarding the

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* Helmholtz, Optique Physiologique, p. 827, 1867.

† *American Journal of Photography*, vol. v, p. 114, Sept. 1, 1862. JOURNAL OF THE FRANKLIN INSTITUTE, 1872.

‡ Jackson's Optics, p. 121, 1867. Helmholtz, Optique Physiologique, p. 812, 1867. Ganot's Physics, p. 486, 1872. Deschanel's Natural Philosophy, p. 950, 1875. This list of citations could be much extended.

stereograph, explanations must be based on what we know of the physiology of sensation; and the external intersection of visual lines may be completely thrown out of consideration. The interpretation which we put upon our sensations depends upon individual experience. In ordinary vision, with both eyes directed upon a given object, a pair of slightly dissimilar retinal pictures are produced, and the result is an unconscious judgment, instantly reached, in regard to its size, form and distance. At the same moment there is a particular degree of contraction in the rectus muscles controlling the eyeballs, and the ciliary muscles encircling the crystalline lenses. The muscular sense contributes along with the retinal sense towards the determination of the judgment. If there be any disturbance in the co-ordination of sensations that are usually associated, the judgment is vitiated and often more or less physical pain is felt as an accompaniment. Assuming that conditions are such as to produce the least possible disturbance, all we can affirm, in reference to the judgment of locality and form put upon the stereoscopic image, is that experience has taught us to interpret retinal sensations that are slightly different in the two eyes, as the signs of an external object possessing three dimensions in space, when the images are made upon parts of the concave retinal surfaces which bear to each other the mathematical relations imposed by the presence of such an object in normal binocular vision. The locality is additionally judged by taking into consideration, consciously or unconsciously, all the peculiarities of each image, and at the same time the muscular sensations which experience has taught us to associate with retinal sensation. If we discard the latter consideration, it should make no difference whether the visual lines are convergent, parallel or divergent, provided there be no change in the mutual relations between the two retinal images.

Supposing binocular vision to be perfectly normal, we may consider the centre of the yellow spot on each retina as a zero-point from which retinal latitude and longitude are measured; and the position of each point of a retinal image corresponding to a given external object may thus be theoretically fixed. It is at once obvious that a point nearer or farther than that upon which attention is directed must be imaged in the two eyes upon retinal points that have not the same longitude. Experience has caused us to associate external singleness with perfect correspondence in position of the two retinal images; and on this has been based the unproved theory that each rod or cone beneath one

retina is in nervous connection with a particular mate in the other eye, thus making single binocular vision a product of anatomical structure. The difference in longitude between the retinal points on which the same external point is imaged may be called the retinal displacement. Theoretically, there should be double vision whenever the slightest retinal displacement exists. Practically, when this displacement is considerable, double images can be perceived; but thus far no minimum limit has been definitely assigned at which we can be sure that the perception of duplication begins. No mathematical interpretation can be put upon such a theory, whether we regard the correspondence as the product of experience or of anatomical structure. The eye is far from being a perfect optical instrument, and focalization is hence never exact. Each sensitive point impressed becomes at once the centre of an area of disturbance, and hence a pair of slightly dissimilar retinal images may apparently coalesce without the perception of duplication in any part. The resultant perception is attended with an enhanced recognition of three dimensions in space, but no fully satisfactory answer has yet been given to the question, how it is that we determine by the nature of the combined retinal image whether imperfect coalescence is due in any given case to the distance of the object being greater or being less than that of the point to which the visual lines are directed.

Assuming that the retinal displacement is great enough to cause apparent duplication of points in the background of a stereoscope picture when the foreground is regarded, and *vice versa,* it is easy to understand how the muscular sense may conduce toward the perception of depth in space. If the eyes be made to follow an object that is brought near and then moved off, as the optic angle increases with the approach of the object, the internal rectus muscles become more strongly contracted. With its recession they become relaxed, and the external rectus muscles become contracted. An association between the muscular sensation and the external reality that ordinarily gives rise to it is soon established. If by any means abnormal vision can be induced, the suggestions due to muscular sensation are still the same in kind. Thus, in Fig. 1, if the attention be transferred from the conjugate points a and a', to b and b', the external rectus muscles must be contracted, and this at once suggests the idea of greater remoteness for the new points regarded. Such increase of contraction would still be

necessitated even if the visual lines, R *a* and L *a′*, had been parallel, or slightly divergent, instead of convergent.

Again, if an object be held a few inches in front of the face, in addition to the contraction of the internal rectus muscles to secure proper direction of the visual lines, we have the ciliary muscles strongly contracted to secure distinct focalization; and the unconscious recognition of proportionality between these associated contractions becomes habitual. If the momentary necessities of distinct vision be such as to disturb this association, the result is either confusion or error in interpreting the sensation. In Fig. 1 the convergence of visual lines, when *a* and *a′* are regarded, is adapted to an object whose position is *A*, while for each eye the ciliary accommodation is for the smaller distance R *a* or L *a′*. The result is slight discomfort and uncertainty in the judgment of distance. The ciliary muscles are too much contracted

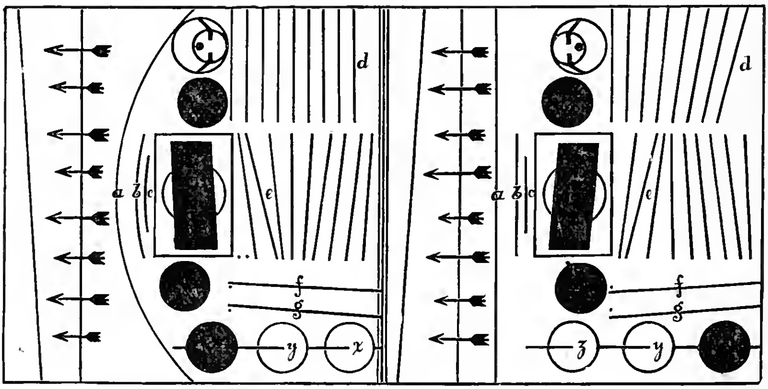

Fig. 2.

for natural association with the condition of the rectus muscles. This disassociation obviously becomes more painful if the distance *a a′* is increased so as to necessitate optic divergence. But in no case can perfect accordance between the adjustments of the ciliary and rectus muscles be secured under the conditions imposed in ordinary stereoscopic vision.

The duplication of images for background points when the foreground is seen single, and *vice versa*, is shown in the accompanying stereograph, Fig. 2, which has been made with a variety of stereoscopic displacements in different parts. The binocular combination can be easily effected, either with the aid of a stereoscope or by use of a screen of card-board, rested with one end against the triple line and the

other against the forehead of the observer. The lines marked *a* will be perfectly combined into a single curve at the middle, but duplicated above and below, the point where theduplication begins being indeterminate. No duplication of the lines *c* is perceptible. There are many other peculiarities which the reader will discover by continuing the examination, scanning separately each part in succession. The truncated cone, the oblique parallelogram, the warped surface, and the wind-vanes will repay close attention. The stereograph is so constructed as to exclude entirely the ordinary elements of mathematical perspective; hence any perception of depth in space is the product of binocular vision alone.

Even with such a stereograph as this the interpretation unconsciously put upon the binocular image may be much modified by varying the muscular conditions under which the perception is attained. In studying these effects, for which the term physiological perspective is con-

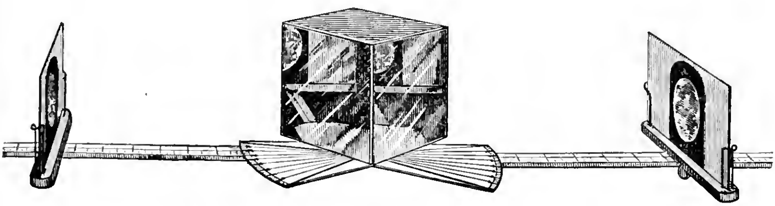

Fig. 3.

venient, the writer devised a graduated reflecting stereoscope, shown in Fig. 3. It is simply an improvement upon Wheatstone's stereoscope, which never came into popular use. A pair of conjugate pictures are placed on the arms, each at a measured distance, such as 50 cm., from the pivot on which these move, while the eyes are as near as possible, one in front of each oblique mirror. If the arms are pulled forward, optic convergence becomes necessary to receive the reflected rays and retain single vision. This involves increased contraction of the internal rectus muscles and associated contraction of the ciliary muscles. Since the real distance of the pictures remains unchanged the ciliary muscles should not change their condition if distinct focalization is retained. The contraction of the internal rectus muscles produces the illusive judgment of nearness; and since the visual angle subtended by the diameter of the picture remains constant, its estimated size diminishes with the estimated distance. The value of the optic angle enclosed by the visual lines is obtained from the divided circle, and the distance of the

optic vertex is easily calculable by the formula already deduced. By pushing the arms slightly back, as represented in the figure, to retain single vision, the excess of contraction must be in the external rectus muscles. As the visual lines are now divergent, the optic angle is negative; the illusive effect is recession of the binocular image, while the distance of the object, and hence the visual angle subtended by it, remains constant.

The mean result of a large number of experiments is shown in the curve, Fig. 4, where successive values of the optic angle are taken as abscissas and estimated distances of the externally projected binocular image as ordinates. The stereoscope was manipulated by an assistant, who

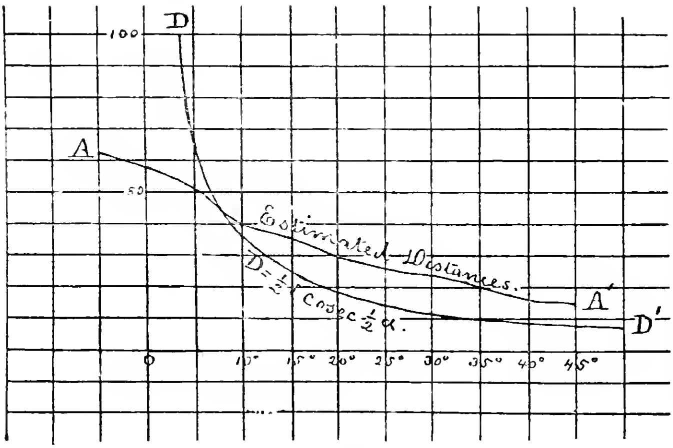

Fig. 4.

also kept the records, of which the writer remained ignorant until after the series of experiments was completed. To prevent too great fatigue these were made at different times in groups. The curve DD′ is calculated from the formula, and gives the successive theoretic positions of the image if the theory of visual triangulation be true. To this curve the axis of ordinates is an asymptote. The curve *AA′* gives the successive positions as observed under the abnormal muscular conditions imposed, the optic angle being varied from —5° (divergence) to +45° (convergence). The two curves intersect quite near to the point whose ordinate is D = 50 cm., corresponding to $a = +7° 20'$; showing that the formula roughly expresses the truth for perfectly normal vision. But on each side of this point the difference between theory and observation becomes striking, the estimated distance and

size of the image being greater or less than that of theory, according as the optic angle is greater or less than that of normal vision. The visual angle remains constant while the optic angle varies, and suggestions due to the condition of the ciliary muscles are antagonistic to those due to the condition of the rectus muscles. As might be expected, the probable error of the whole series is large, being $\pm$ 8 mm., and the curve AA' is not regular, but its general import is unmistakable. The localization of the external image is in no way dependent upon intersection of visual lines, but largely affected by the temporary condition of the muscles of the eyes. The curve AA' represents the result of experiments upon the writer alone; but similar results have been obtained from the examination of several other persons, slight variations being such as might be expected from difference in personal organization.

REPORT ON EUROPEAN SEWERAGE SYSTEMS, WITH SPECIAL REFERENCE TO THE NEEDS OF THE CITY OF PHILADELPHIA.

By Rudolph Hering, C.E.

(Continued from page 201.)

III. Street Inlets or Gullies.

After having briefly treated of that part of the system which collects and conveys the house sewage to the sewers, which is to a certain extent in private hands, I will now examine into the design and construction of the appliances for collecting and conveying the street-wash to the sewers.

In Philadelphia these appliances are called simply inlets, in other cities, catch-basins and in Europe, gullies. A great number of designs are in use.*

Inlets in our city are usually placed at the corners of street intersections. The usual size No. 1 has an opening of 4 feet 6 inches $\times$ 10 inches, a basin for catching silt 2 feet below the outlet, 4 inches 6 feet long and 1 foot 4 inches wide, with a water-trap 4 inches deep. They are built of brick, with flagstones for the back and the trap, and have

*See Appendix No. 4.

a cast iron cover. A so-called "neck" or branch of brick, 2 feet in diameter connects them with the sewer. A common trouble experienced is a failure of the trap and the escape of sewer air.

It is not an uncommon case, as already mentioned, that the intersection of several streets forms a depression, and this causes the inlets to become more easily and rapidly silted up and in consequence thereof, sometimes, the territory to be flooded. In Europe these objections are not experienced, or only in a slight degree. There the gullies are less expensive and less unsightly. The location is rarely at the immediate corner of the intersection, mostly a short distance above it. Depressions, such as we have, are consistently avoided. The inlets are smaller, are placed closer together, and the attention given to their cleaning is much greater in all of the larger cities than here.

In examining the designs we find some that have silt-basins to catch the sand and heavy or bulky matter, washed into them from the streets, and some that discharge directly into the sewer. The latter I noticed only in Paris and Hamburg. In both of these cities circumstances justify the absence of silt-basins. The great attention given to street cleaning in Paris, as well as the facilities for cleaning the sewers, has made it seem expedient to wash much of the road detritus off the surface into them and then to artificially remove it through them to an outfall. In Hamburg the silt is not objectionable in the sewers because it can be readily removed at any time, by natural flushing. The Alster lakes, situated almost within the city, are used for this purpose and from them a large quantity of water can be sent through the greater number of sewers at a velocity sufficient to wash the silt into the river.

In all other cities, catch-basins were preferred even where the streets are well cleaned. The designs differ in different places. The size is principally regulated by the character of the pavement and by the degree of care which can be given to the cleaning of the streets and sewers.

In Frankfort, a bucket perforated near the top, is placed in the basin to catch the silt, and when filled, can be readily lifted out, emptied and returned. In other cities the silt is removed by scoops.

When sewers are properly built, ventilated and maintained, traps are almost or quite needless; the air in the sewer does not become so foul as to be objectionable when it arises from the inlets. In Paris and Hamburg they were left out at the beginning, and their absence

has never caused the slightest nuisance. Several cities have had the traps removed, prominently among which is Leeds, and it was found that where the sewers were well cleaned and the inlets were not too near the windows, the odor, if there was any, escaping from them, was unnoticed. The additional aid thus given to ventilation, even further reduced the development of noxious gases.

To determine the design of an inlet which is best suited to our circumstances, I shall examine into each one of its features separately.

Until the streets are cleaned in a manner and to a degree which is even rare in Europe, the silt-basins can evidently not be omitted, especially as we have no natural means of flushing our sewers with large quantities of water.

If we cannot do without the basin, the question will then be, of what size to make it? Here again the usual condition of our streets will not permit as small a size as is common in Europe. The comparatively great amount of dirt and silt left on our streets would quickly fill them up during a sudden storm, or, if kept sufficiently stirred up by a heavy shower it would be washed into the sewers and thus defeat the object of the basin. In the sewers the silt acts as a retarding element to the flow of sewage by making a flatter channel, which causes further deposits and also a mingling of the silt with the decomposing filth. As insufficient care in the cleaning of streets, compared with European cities, is a given fact for us, it is necessary to guard against the ill effects upon the sewers as much as possible. The basins, therefore, should be large and deep enough to retain a reasonable amount of silt, varying with the character and width of the road, which a careful examination may determine. Yet this amount need not be greater than what accumulates from one storm, as it should be removed early, before decomposition can make its retention objectionable. For the paved sections of our city I think a basin holding from 6 to 12 cubic feet of silt, according to the size and grade of the surface drained, is of ample capacity. For macadamized streets and rural sections a greater size is necessary.

The next feature of the inlet to be examined is the trap. Unless our sewers were built and maintained as well as those in European cities, where inlets have no traps, it would not be advisable for us to omit them. Of all traps the water-seal is for this purpose the best, simplest and most economical. During a long drought it may, how-

ever, be necessary to run water into them to guard against unsealing by evaporation.

Another part of the inlet is the "neck," or connecting branch with the sewer. As its service is to lead away the water entering the inlet, its size is thereby determined. A diameter from 6 inches to 12 inches is in all cases sufficient. I have nowhere, except in Paris and Vienna seen greater ones, even under essentially the same conditions as in Philadelphia. The great disatvantages resulting from the custom of building necks of 2 feet in diameter are the same as those which I shall mention later, when speaking of the sewers themselves. It will suffice now to state that terra-cotta pipes, of diameters only sufficient to discharge the maximum quantity of water, will give much less chance for deposit, and for that reason should be preferred. They can be inspected and cleaned as well, if they are laid in straight lines; they are as durable and not more expensive.

In Paris the necks (*branchements de bouche*) are large enough, like all sewers, to be walked through, but they are frequently cleaned. Notwithstanding this, they are the least efficient part of the system, and the odor arising from the street-inlets has been traced mainly to the decomposing matter lodging in them, than to the air from the sewers. In Vienna, the necks, also large enough to be entered, are but little better than our own, although they are frequently and regularly cleaned. On the other hand no complaint has arisen in any city, as far as I could ascertain, from the use of terra-cotta pipes. Little doubt, therefore, remains in my mind that much of the odor escaping from our inlets is due, as in Paris, to the decomposition of matter in the necks. And this seems to be confirmed by the fact that when broken into they present as foul a condition as the average branch sewer.

I will now consider the proper location for the inlet. Our custom is to place them directly at the intersection of the curblines of two streets. I found this rarely done in Europe, not only because it is unsightly, but because it makes a deep gutter for pedestrians to step over and into which the wheels of vehicles are apt to slip in turning the corner, which strains or even breaks them. Still another reason is that the position across a corner is not the best one to receive the water as it is obliged to turn a considerable angle, from 45 degrees to 135 degrees, before it drops into the basin, which impedes its velocity, and

therefore, needs a larger inlet than if it is situated, as in Europe, on the line of the curb in the block.

When the grade of the gutter continues around a corner, the best location for the inlet is at a point about 8 or 10 feet above the sidewalk crossing, which entirely abolishes the gutter at the corner. When the grade of the gutter is lowest at the intersection, then it may be a question to consider in such case whether it is best to put one large inlet at the corner or two smaller ones, each about 20 feet from it. In frequented and principal streets, the latter is always preferred in Europe. In small streets, or in the suburbs, the corner inlet would not be so objectionable. There is no reason why the same plan should not be as advantageous in our own city.

Inlets, when they have catch-basins attached, are, at best, more or less objectionable, unless they are cleaned frequently and carefully. They should, therefore, be avoided, whenever possible, unless they can relieve a greater nuisance. There is no objection to rain-water running in and over the streets in moderate quantities during a storm. If inlets, therefore, are used only for the purpose of receiving rain-water, which is the case when a sewer has been built in a street and the houses have been connected, then they can be left out, both for a short distance from the river and from the water-shed line of the drainage area. This distance is governed by the topography and can easily be as much as several blocks. For instance, all the water falling east of Front, or even Second street, between Fairmount and Washington avenues, might readily run off on the surface into the Delaware River. At the highest parts of many of our areas the storm-water could also run over the surface for two or three blocks, before it would accumulate so as to become troublesome and require an inlet. These points are generally considered in Europe, and a reduction of the number of inlets is effected. In fact, it has been proposed* to keep the rain-water entirely on the streets by leading it away in covered gutters, but this I am confident is impracticable, at least in our city.

To have the inlets a short distance above the corner and to let rain-water run over an intersection of streets requires an adjustment of the grade of the pavement, which must briefly be noticed. In the first

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*Col. G. E. Waring, Jr. Sanitary Condition of New York. *Scribner's Monthly*, June, 1881.

case, it can be raised to about three or four inches below the side-walk, giving an easy step and avoiding a gutter-crossing. In the other case, the gradients and crown of the intersection would require to be such that water can run across readily. Modern pavements will generally allow this condition. The Belgian, asphalt and wood pavements require but a slight chamber, and with them this saving in the number of inlets, often made use of in Europe, could also be effected here.

Regarding the construction of inlets, I must state, that our practice is inferior to that which I have noticed elsewhere. When a silt-basin is necessary, it must be water-tight, but especially so when the water is to form a trap against the exit of sewer-air. The use of flagstones to face the walls is not likely to make as water-tight a basin as a well cemented wall of brick work alone, or as one made of iron or concrete, the materials commonly used in Europe. Nor is the absence of an inspection, while they are being built, likely to decrease this trouble. From the designs I have collected it will not be difficult to adapt one or the other to our conditions as mentioned, which would be much more suitable than our present one.

The cost of inlets, such as would be proper will not be greater than the cost of the present ones, provided the quality of material and workmanship is the same. And a saving may even be effected by a judicious distribution, especially in connection with the paving of the streets, near the highest and lowest parts of the drainage areas, as indicated.

Finally, whether the inlets discharge water into the sewers of a combined system or into separate rain-water channels, it does not alter the above-mentioned points governing their design, except that it may be expedient and advisable in the latter case to omit the trap and thereby to obtain better ventilation.

IV. Sewers.

I have now examined those parts of the system by which the sewage is collected and brought into the sewers. It will next be in order to inquire into the features of the sewers themselves.

(*a*) Shape.—All sewers in Philadelphia are, as a rule, built of circular shape, from the largest to the smallest, except where sufficient height is not obtainable, when sections with flat inverts of varying forms are used. That these shapes are essentially faulty, and undoubtedly a most prominent cause of the present objectionable con-

dition of the sewers I shall endeavor to show by a theoretical consideration confirmed by the long practical experience had elsewhere.

The best shape of a channel in which flowing water is to receive the least possible resistance to its flow is the semi-circle. As the sanitary requirements of a system demand in the first place a quick and complete removal of the sewage, every element of design and construction which favors this should therefore be considered.

A sewer for the combined system is to answer two objects, the conveyance of a continual stream of sewage and of the periodical stream of storm-water, which is many times greater in quantity. It would, therefore, strictly be necessary to give each of the two streams a semi-circular section. This is impossible in the same channel, and only an approach to it can be had at best. If a semi-circular section is given to the sewage, the storm-water must have a different one, and *vice versa*.

To decide which of the two cases is to be preferred, it must be considered; that the sewage is a continuous stream, whereas rain-water enters periodically; that, further, sewage is a heterogeneous mas consisting of floating and suspended glutinous particles which readily adhere to the frictional surface, while rain-water is free from such matter and comparatively clean; and, finally, that the sewage, from its decomposing nature, should be conveyed as swiftly as possible through the sewers, while with rain-water this requirement is not so needful.

From all of these essential points it will be seen that the semi-circular section should be given to the sewage in preference to the storm-water, because its flow is continuous and its mass heterogeneous, carrying glutinous and adhering matter subject to rapid decomposition. If the usual flow is carried in a channel of this shape the storm-water must be conveyed in some other. The combination gives the common egg-shape. That this shape, which *theoretically* is shown to be superior to the circle, is also *practically* the best, has been shown by a long experience in Europe. Not one of the large cities with any pretence of a sewerage system has retained the circular section for large sewers, carrying both rain-water and sewage. All have long ago adopted the egg-shape, and not a single objection is made to it, whereas the circular form has a very serious one.

The relatively small amount of sewage is necessarily spread out to a shallow segmental section. This decreases not only the mean velocity,

but particularly the velocity along the margin, and, therefore, causes the suspended particles to deposit. For this reason we usually see in a circular sewer a stream of sewage meandering along the bottom in irregular lines, building up a small bank of filth on each side, whereas, by a properly designed egg-shaped section this is exceedingly rare, if ever, observed.

The proper shape of a "combined" sewer must then be determined as follows: The radius of the invert, which is to carry the sewage, should be nearly the same as for a semi-circular channel, just large enough to be filled by the ordinary flow of sewage. The other dimensions are governed by the quantity of rain-water to be provided for, and by the laws of stability. An egg-hape which is thus obtained is the only rational one for the combined system. Some sewers, however, require a different treatment. An intercepter, which is designed only for the conveyance of sewage, and, therefore, a more uniform flow, should according to what has been said, have a circular section, and in Europe all such sewers have this form or a near approach to it. Again, a sewer which is so small that it can be built of vitrified pipes is also given a circular section with advantage, for not only their smoothness prevents much adhesion along the sides, but also the greater facility for obtaining a true circular form for every single pipe, therefore, avoiding a series of projections which are exceedingly detrimental to the flow of sewage, makes this form preferable.

To sum up, intercepting sewers, which we require in the future, and also pipe-sewers, should be circular, but all others should be egg-shaped.

Considering the point, financially, it will be found that the latter will not add any expense. On the contrary, it will in many cases be cheaper. By having less width it decreases the amount of excavation; by substituting it for our present minimum size of 3 feet diameter, it would, by retaining the same height for the workmen to pass, also require less brickwork for nearly all cases, and by having a less span of arch, make it proportionately stronger.

If this is the conclusion, then nearly all of our sewers are improperly shaped. It would, of course, be entirely impracticable to replace them by others, although it may be advisable in a few cases. Yet many of them could be gradually so altered, at no great expense, as to sufficiently conform to the above demands. It would simply be

necessary to form a new invert inside of the sewer, without disturbing any part of it, either by means of half pipes backed by concrete or of concrete entirely, making a section somewhat like the Paris sewers, although much smaller, or the Fourteenth street sewer in Washington, D. C., where a similar plan was adopted.

To finally indicate the conditions of sectional shape for the *separate* system, it suffices to state that, according to what has been said, the sewers conveying sewage alone should be circular, and those for the rain-water can either be circular or, still better, egg-shaped, in order to give the diminishing quantity of water at the end of a rain the greatest possible flushing power.

(*b*) SIZE.—The sizes of our sewers have been determined by means of two considerations. First, they are proportioned to lead away an amount of storm-water equal to one cubic foot per second from every acre of the area, however large, which is equivalent to a rainfall of one inch per hour getting into the sewers. Secondly, the usual minimum size has been three feet in diameter. I shall consider these two points separately.

It is necessary to know the extent and magnitude of storms and the amount of water which flows into the sewers. Evidently, then, to have exact data on this question, so that the sewers will be neither too small nor too large is a matter of great economy. Special examinations have never been made in our city with reference to this matter, and, nowhere else have they yet been extended to limits which could be applied safely to all other localities. In order to proportion the size of our sewers in the most economical manner it would be necessary to make a series of observations, neither difficult nor very expensive to carry out, of the extent, intensity and duration of the heavy showers or storms passing over the city and its immediate vicinity, and a gauging of their effects in the sewers. The saving caused by such observations in obtaining rational sizes would be much more than would pay for their expense.

But until such local data can be procured we are left to obtain a guide from data collected at other places.

I have attached a table,* showing the duration and intensity of some heavy storms in Europe and in Philadelphia. By comparing, it will be seen that the intensity and duration of storms in Philadelphia are

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*See Appendix No. 2.

certainly not greater than those elsewhere observed. We may, therefore, accept other experience to a certain extent as indicating what our own conditions might give. To appreciate the opinions held in Europe on the quantity of rain-water to be provided for I shall quote from the report of the Metropolitan Board of Works, 1878, p. 110, in the language of their celebrated engineer, Sir J. W. Bazalgette: "The intercepting sewers were not designed for the purpose of taking all the waters which fall during excessive rainstorms, such, for instance, as the one which occured on the 10th and 11th of April, 1878, when from observations made at forty-three stations in and around the metropolis, it was estimated that an average of 2·64 inches of rain had fallen over the whole of the metropolitan area within a period of nineteen hours. To intercept such a volume as resulted from this rain would have necessitated sewers of the capacity of rivers, and which would have been nearly empty, excepting an occasion of extraordinary fall."

A rainfall of 2·64 inches is according to this statement already considered excessive in London, yet there is a record of six inches having fallen in one and one-half hours.

The storm relief sewers which are being built and are further contemplated in London are proportioned according to Hawkley's formula:

$$\textit{Log diameter in inches} = \frac{\text{3 log area in acres} + \text{log length in which the sewer falls one foot} + 6{\cdot}8.}{10}$$

It gives a diminishing quantity of rain running off per acre, as the area increases in size.

In no European city did I find the proportioning of sewers for a large area to be in a direct ratio with its size, as customary here. In fact our method elicited severe criticism.

If a sewer, according to our calculation, has a correct size at the lower end of the drainage area it will be too small near its higher part; and if its capacity is ample near the latter it will be unnecessarily large at the lower end. To suppose that the amount of water flowing off is in direct proportion to the area, although it is true for small ones, is not true for large ones measuring hundreds or thousands of acres.

Experience has amply shown that the amount of water reaching sewers from a certain rainfall depends: 1, on the size of the area, because the heaviest fall is not spread over a lage surface at the same

time, and its duration is not long enough to permit the water from the highest parts of a large area to reach the low ones before the rain has slackened; 2, on the general grade of the area, because the flatter it is the less velocity the water will have, and the greater will be the time for a portion to soak away; 3, on the character of the surface, whether it is urban or rural, paved or covered with buildings, gardens, lawns or fields, which also influences the amount that soaks away.

With these points in view, the experience gained has been framed in formulas of which one merits special attention. Mr. Burkli-Ziegler* carefully collected the known data on the subject and compiled them into the following formula:

The water reaching a sewer is equal to the average intensity of the rain during the period of heaviest fall, multiplied by a coefficient depending on the character of the surface, multiplied by the fourth root of the general grade of the area per 1000, divided by the area drained; or,

$$q = r \times c \sqrt[4]{\frac{s}{a}}$$

The coefficient $c = \cdot 75$, for paved streets and densely built up areas, graduates to $c = \cdot 31$ for suburbs with gardens, lawns, and macadamized streets.

This formula is compiled from observations made in London, Paris, and various parts of Germany and Switzerland, including rainfalls similar to our own, and slopes up to 10 feet per hundred and surfaces with city and country characteristics. Its results agree very clossly with all the available data, and I consider it, therefore, a much better guide for us than the present "rule of three proportioning" of sewers.

To show the effect of this formula, I will apply it to our Mill Creek sewer at the lower end of its drainage area, which in round numbers is 3100 acres with an average slope of 5 feet per 1000. I shall suppose a rainfall at the rate of three inches per hour, the provision for which is as much as municipal economy will justify, and shall assume the coefficient depending on the nature of the surface to be ·50, which fairly represents suburban characteristics.

With these data we obtain the quantity of water reaching the lower part of the area.

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*Burkli-Ziegler, *Abflussmengen städtischer Abzugscanäle*, Zürich, 1881.

$$q = 3 \times \cdot 5 \sqrt[4]{\frac{5}{3100}} = 3 \times \cdot 5 \times \frac{1}{5} = 0 \cdot 3$$

corresponding to about one-third of an inch per hour, which implies a size of only one-third of the present one, or a diameter of twelve feet instead of twenty. Observations which I have made of rainfalls during the construction of various parts of this sewer confirm this result.

It is thus evident that a great economy of expenditure is connected with this consideration.

If sewers are proportioned with the aid of this formula, or any other compiled from actual and varied experience, instead of by the rule of three, which has no confirmation in practice outside of very small areas, more rational sizes would certainly be obtained than at present, and a great saving of money effected.

After having considered the quantity of storm-water to be conveyed by sewers, which can have no overflows or relief channels, we must now consider what quantity of sewage is to be conveyed by sewers, which either receive no rain-water or only a small quantity, the rest escaping into other channels.

It is a usual custom in Europe, and it is generally found sufficiently accurate to consider the amount of sewage from a house to be equal to the amount of water supply furnished to it. And it is further assumed that one-half of the daily amount is discharged in six to nine hours. With this assumption the maximum flow of sewage can be obtained. For the separate system it would readily designate the size of the pipes, which, for safety, are usually considered as only half filled by sewage. For intercepting sewers, or any others with storm-water overflows, a small portion of rain-water, the first wash from the surface, should be allowed for. This quantity is usually assumed as $\frac{1}{50}$ to $\frac{1}{100}$ of an inch per hour, according to local conditions.

The formulæ used in Europe to determine the mean velocity of the sewage are Eytelwein's, Bazin's, Bazalgette's, and Kutter's, all of which, when properly used, were found to give sufficiently near and reliable results.

Regarding our minimum size of sewers which has been limited to three feet diameter, even to the summits where only two or three houses are to be drained, I have the following remarks to make: This limit was selected on account of being the least which will allow workmen to pass through to clean them. There is at present a divi-

sion of opinion regarding the expediency of having sewers large enough to be entered, or whether to use pipe-sewers, if the amount of water to be discharged will at all permit of the latter. As the difference of expense is often not great, it is preferred to make them passable. On the other hand, it is urged that to make them larger than necessary, impairs the rapidity of discharge and offers a storage for a large quantity of sewer gases. Pipe sewers are generally not used in Liverpool, Paris, and Vienna; in Frankfort and Hamburg, only under certain conditions, whereas in London and most English cities, in Berlin and Danzig, pipe-sewers are preferred wherever possible.

Their success depends on three elements, firstly, on faultless pipes of true dimensions and shape, secondly, on a faithful and careful laying, and thirdly, on a regular inspection, and in most cases, flushing. When these conditions can be obtained a pipe-sewer is superior to a larger one of brick, because of the smoothness of the perimeter, by which not only the velocity is increased but the adherence of decomposing matter greatly prevented.

When any of these conditions are not obtainable, and the slight additional cost for brick sewers is not objected to, the latter will generally be found preferable.

The proper course to be pursued in our city, therefore, is to lay pipe-sewers in preference, when good execution and maintenance can be commanded, otherwise or until then to build brick sewers of egg-shape three feet high in their stead.

The minimum diameter used for common pipe-sewers I found to be nine inches, for house branches usually six inches.

(*c*) Grade.—I shall now examine into the proper grade of a sewer, which is of no less importance than the size.

It is commonly supposed that in many of our districts the gradients must naturally be very light, and that difficulties of drainage result therefrom, yet these difficulties are very slight, for we can give our sewers in any part of the city sufficient fall for a self-cleansing velocity. In Europe, 1:2000 to 1:3000 are common grades for main intercepting sewers, and 1:1000 for valley line sewers, whereas our usual minimum has been steeper than 1:1000. On the other hand, we have many heavy grades, some reaching five feet per hundred feet; and quite ordinary grades are one and two feet per hundred. In Europe, such grades have been shown to be very detrimental and destructive to the sewers, and were deprecated in many cities.

The great velocity created by a steep grade causes the silt carried by the sewage to scour the bottom to an injurious extent, as we have already noticed ourselves; for instance, at Twenty-third and Spring Garden streets, where some of the bricks were worn down three inches in six years by a grade of over four feet per hundred, causing a theoretical velocity of over twenty feet per second.

Mr. Rawlinson, the highest authority on modern sewerage, says* that the velocity in a sewer should not exceed six feet per second, and by considering this as a limit, a maximum gradient for each size can be obtained. This recommendation is generally acted upon, and I seldom found cases where grades were heavier.

Again, a steep gradient during the ordinary flow decreases the section of flowing water, and consequently injures its flushing capacity.

In steep sewers, therefore, we find banks of deposits at the sides of the streams between which it runs. In Berlin, this point was considered to be so serious that the maximum velocity in small sewers was limited to about four feet per second with corresponding grades, even when the ground permitted them to be greater.

A means to prevent a steep grade is to have occasional drops or tumbling bays, where the sewage suddenly drops vertically and then resumes its course. A series of steps, used sometimes for this purpose, was found to be much inferior to a vertical tumbling bay, with alternate drops, because the sewage can deposit more filth, and during storms, when the retarding action is most needed, it is least accomplished by them.

A *minimum* grade to be given will depend on the character of the sewage, whether carrying much silt or not, and also on the mass of water ordinarily flowing in them. The least bottom velocity should be sufficient to prevent a deposit of heavy silt. Numerous observations and tables have been recorded which can be used for this purpose, to which I refer.

In our city no distinction has been made between the grades for the ordinary and for the storm-water flows.

The grade producing the velocity of the ordinary flow, which is comparatively slight, may be assumed to be the same as the grade of the bottom of the sewer, which should be regulated accordingly and

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*Suggestions of Local Government Board.

with attention to the points just mentioned. But the grade producing the velocity of the storm-water flow must be considered as being the surface of the water or the hydraulic gradient, especially near the outfall, where at high stages of the river, the sewer is partially or wholly submerged. In this case the velocity is always less than that produced by the grade of the sewer, and it may, therefore, seriously impair its capacity. The troubles of the Cohocksink Creek sewer are partially due to this cause.

At Pine street, near the Delaware, the six-foot sewer, west of Front street, might have been continued to the river, with the same size, instead of by means of a twin-sewer, chamber and rectangular outfall, if this question had been considered. And the Palmer street sewer might have been laid at its outlet to a much lower depth, without interfering in the least with its discharge, and thus saved the use of the property as a wharf.

Concerning the grades, when the sewage and rain-water are *separated*, nothing further need be added.

(*d*) Depth of Sewers.—But little is to be said regarding the depth of sewers. It is governed by the usual depth of cellars, as the sewers should always, if possible, be below them. As our cellars are generally five and six feet below the surface, the water in the sewers, allowing for a fall from the house, should not rise higher than seven to eight feet below the surface, according to which the depth of the bottom of the sewer can be regulated. In Europe, as a rule, the depth is greater, but the cellars are also deeper. In Frankfort, the average depth of the bottom of the sewer is seventeen feet below the surface, the deepest average I noticed anywhere.

In Philadelphia, the bottom has varied from nine to twelve below the ground, which, if the sewer does not hold more than two feet of water would generally be within the proper limits.

For the separate system the question of depth is important. The sewers proper must be as deep as those of the combined, so as to drain and protect the cellars. But the rain-water channels, being solely for the purpose of removing rain-water from the surface, can be as shallow as other considerations, the stability and grade will admit of. A great saving in the cost of excavation may therefore be secured for them.

(*e*) Construction.—The sewers in our city were formally built with much less care than at present, to which a large yearly percentage of breaks testifies. Lately, the main sewers have been built of

good materials and with sufficient care, so that their permanent stability is secured. The construction of the branch sewers, however, has only slightly improved, and the consequence cannot be otherwise than detrimental. The inverts are generally laid dry, or with so little and weak mortar that the effect is the same. The bricks used are usually warped and rough, presenting, when laid, a very uneven surface for the sewage to flow upon, and causing a considerable retention of decomposing matter. The four-inch ring used for a sewer of three feet diameter is, unless the work is very carefully done, not sufficient for stability, and a flattening of the arch, if not an actual collapse, is a common result.

The great difference in the construction of the sewers abroad is striking. The necessity of stability not only is fully appreciated, but also of giving the surface upon which the sewage flows the greatest practicable degree of smoothness, in order to avoid the retention of foul matter. As this is, perhaps, the most essential feature of good sewerage, its importance can hardly be over-estimated, and it cannot be too strongly urged upon our city. I have found that quite generally none but the best obtainable material was used, the hardest and most perfect-shaped bricks, the strongest Portland or Vassy cement, and the best and most carefully selected pipes. While inferior materials were sometimes admissible for works above ground, none but the best were allowed for sewers. The care given to the execution of the works, especially to make them water-tight, is correspondingly good. The more perfect sanitary condition of the modern European sewers is the natural result, and the economy of this care therefore becomes evident.

Regarding the thickness of materials for pipe, brick or other sewers, I refer to the accompanying drawings. It will be seen that for branch sewers better dimensions are used than here. Among the materials employed vitrified clay pipes of the best quality and true shapes are preferred for small sewers, up to fifteen inches in diameter, but seldom over this size. Iron pipes are used sometimes for house branches, and in Amsterdam even for the entire (Liernur) system. Bricks are the most common material used for large sewers. In nearly all cities they are wedge-shaped, at least for the arches and inverts. These cost but a trifle more and greatly increase the stability of arches between two and five feet diameters.

Bricks are wet before being used. They are laid in strong cement

mortar and carefully lined, and the joints are struck very smoothly, similarly to the back walls of our average dwelling-houses. Sewers are often built entirely of concrete, which material, as a rule, is preferred if within reasonable cost. A mould or centre of cast-iron, smoothly planed, is carefully aligned, the concrete stamped around it, and then left to set for several days. The best examples are found in Vienna, Paris and London where, especially in the first city, the inner surface in the best sewers was found to be as smooth as the average finished wall of a room.

The materials which will be economical in our city are vitrified pipes for sewers up to fifteen inches, or perhaps eighteen inches diameter, and bricks for the larger sizes. Concrete will hardly become advisable, because the clean, sharp gravel necessary for it is not found in this vicinity. The pipes should be very carefully selected, not only for hardness but for proper shape, so that no projections, bad joints or other imperfections will occur. The bricks should be of a better class, at least for the inner surface, to give a greater degree of smoothness to it. The mortar should be mixed with the best attainable cement, viz., the English or American Portland, or the better brands of Rosendale cement, with such proportions of sand as will secure a firm and hard set. Lime and cheaper cements are never used in Europe.

Regarding the execution of the work, it would be well to bestow greater attention than heretofore upon the three essential features in the construction of a sewer, viz., stability, water-tight joints and a smooth interior surface, which can be secured by proper dimensions and faithful labor.*

With these points held in view, our sewers could be brought up to standards, common not only in Europe, but also in some of our own sister cities, such as Providence, Boston, and New Haven.

(To be continued.)

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*Bricks should have their joints carefully pointed after the centres are drawn, in branch as well as main sewers, and should never be laid dry, as this at once defeats the object of a perfect sewer, in allowing at certain times the sewage to soak into the surrounding soil similarly to a cesspool, which nuisance a sewer is precisely intended to abate. Pipe-sewers require even greater care on the part of the mechanic, because imperfections can more readily cause obstructions, and access to them is more difficult. But when properly built and maintained, pipes are superior to brick, as already mentioned, and the greater attention necessary in their execution is amply repaid, as shown by their being preferred in most European cities.

THE MANUFACTURE OF POTASH ALUM FROM FELDSPAR.

BY HENRY PEMBERTON, JR.

[A paper read before the Chemical Section of the Franklin Institute, Sept. 5, 1882.]

In the August number of the JOURNAL OF THE FRANKLIN INSTITUTE there is an article by John Spiller (first published in the *Journal of the Society of Chemical Industry*, Manchester, England, April, 1882), in which it is proposed to manufacture potash alum from feldspar, by treatment with sulphuric acid and a fluoride, the latter being either fluorspar or cryolite.

Feldspar is a mineral occurring in immense deposits, and containing potash and alumina sufficient to give on a practical scale an amount of alum equal in weight to the quantity of feldspar treated. It can be had, under favorable circumstances, at a cost not exceeding a few dollars per ton. The fluorspar is equally cheap, and the sulphuric acid (as "chamber acid") is manufactured in this country at about $8 a ton. The resulting alum finds a ready market at $40 to $45 per ton, and the margin of profit, therefore, seems to be a very fair one.

I propose to show, however, that the above rosy view is a deceptive one, so far, at least, as the American market is concerned, and that the process is not only a technically difficult one, but will prove to be so expensive that the alum will cost about as much as it will bring.

Taking the typical feldspar selected by the author, we have, as its composition,

Silica,	65·00
Alumina,	17·85
Potash,	12·31
Iron, lime, magnesia, soda, etc., by difference,	4·84
	100·00

To volatilize the 65 per cent. silica as tetrafluoride will require 169 parts of fluorspar, supposing the latter to be chemically pure. We therefore will have the following percentages of bases and acid employed in treating 100 parts of feldspar:

17·85 per cent.	alumina,	requiring	42·00 per cent.		SO_3
12·31 "	potash,	"	10·45	"	"
169·00 "	fluorspar,	"	173·33	"	"
	Total SO_3 required =		225·78		

This is equivalent to 443 parts of "chamber acid" containing 51 per cent. anhydride. The acid for the small quantity of other bases present is here neglected.

The author finds it "necessary to get rid of the excess of sulphuric acid by thoroughly heating the decomposed mass in a current of air before dissolving." Any one familiar with the behavior of alum at a high heat—especially when mixed with three times it weight of sulphate of lime—will fight shy of this operation on the large scale.

Mr. Spiller is perfectly right in asserting that there will be an excess of sulphuric acid in the decomposed mass, even when the quantity theoretically necessary is used. Experience has proved, in decomposing any solid material with acid in this manner, that from 10 to 15 per cent. of the material escapes the action of the acid, a corresponding amount of acid also being left uncombined. The reason for this being that the quantity of already decomposed material acts as a diluent of, and a mechanical separator between the remaining small quantities of acid and base. The most rational method of obviating this difficulty is to use a proportionally smaller quantity of acid. Charging the above formula, therefore, with only 85 per cent. of the acid given, and assuming that the feldspar, when mined, hauled, calcined (to render friable), ground and bolted, costs \$5 per ton, and the fluorspar \$3 per ton, we have, as the cost of the ingredients,

2000 lbs. feldspar, at \$5.00,	\$5.00	
3380 " fluorspar, at \$3.00,	5.07	
7531 " 50°B. acid, at \$8.00,	30.12	
		\$40.19
Labor for mixing, leaching, evaporating, crystallizing and packing, with coal for evaporating, at least,		5.00
Eight barrels, at 20c.,		1.60
Yield = 2,000 lbs. alum, costing,		\$46.79

Or a little over $2\frac{1}{4}$c. per pound, not including general expenses, salaries, insurances, etc. This is just about the present market price for crystal alum.

It will be observed that the weak point in the above process is the quantity of acid required to liberate the fluorine from the fluorspar, nearly 80 per cent. of the acid charged being used for this purpose. About three tons of sulphate of lime, therefore, are formed, from this acid, for every ton of alum made. This bulky, insoluble, useless

material, has to be leached to extract the alum, requiring much water, giving weak liquors, and, consequently, wasting much coal in the subsequent concentration.

Recognizing these objections, Mr. Spiller proposes cryolite as the source of fluorine, in place of fluorspar.

This is an idea, if possible, still more unfortunate than the former one. In the first place, cryolite is expensive—exceedingly expensive when compared with the other materials used. In the second place, it yields the wrong alkali—soda, in place of potash. And, thirdly, even if the necessary potash were added (from Stassfurt salts), the resulting Glauber's salt—formed from the soda—would be left as a white elephant upon the hands of the manufacturer; all the whiter from the fact that it is contaminated to the saturation point with potash alum.

It is proposed to pass the fluoride of silicon, evolved from the above decompositions, into water, and to sell the resulting silica and hydrofluosilicic acid. As the alum industry is one amounting to hundreds of tons, whilst the most that can be claimed for the silica (for polishing powder) is that it can be disposed of by the hundreds of pounds, the odds against the silica are as 2000 to 1. Still less can be said for the hydrofluosilicic acid.

So it does not appear that there is much of value in Mr. Spiller's idea. It is true that his article was written for the English market. There the price for materials and labor is unquestionably lower than here. So also is the price the alum will bring. The argument against the process, therefore, will hold good in either longitude.

EDITOR JOURNAL FRANKLIN INSTITUTE:

The metal iridium has by reason of its extreme hardness and infusibility given great trouble to work. But comparatively recently Mr. John Holland, of Cincinnati, who had long been using the metal for the tips of gold pens, discovered how to drill and work it, and now he announces that he has made a 12-inch circular saw with teeth tipped with iridium—to be used for sawing hard wood. R. GRIMSHAW.

A CORRECTION.—ON THE ANALYSIS OF HELVITE.

By Reuben Haines.

[Read before the Chemical Section, Franklin Institute, September 5, 1882.

Since the analysis of helvite from Amelia Court House, Va., was published in this journal (July, 1882), I have received from Mr. H. C. Lewis another sample of this mineral of much larger amount from the same locality. A re-examination of the specific gravity shows the previous determination to have been erroneous. It is now found to be 3·29. Dana gives the specific gravity as varying from 3·1 to 3·3. The error doubtless originated in attempting to work on too small a quantity of the mineral, less than three-tenths of a gramme having been used. For the determination now given 1·176 gramme were taken and the same portion afterwards used for general analysis. The material was very carefully picked over several times under a magnifying lens, and only the larger and more uniformly yellow-colored crystals selected. The largest of these, however, scarcely exceeded from one-twelfth to sixteenth of an inch in diameter. Mingled with the impure mineral sent me was a considerable amount of orthoclase felspar, to which some of the helvite adhered strongly, and also a number of crystals of pale-red topazolite (Lewis), a variety of garnet were observed mixed with the helvite, some adhering to the latter or partially imbedded in it.

A new analysis of the purified helvite gave total SiO_2, 32·49 per cent., of which the insoluble gangue was 5·17 per cent. The latter was determined on about half a gram of another portion of equally well-picked mineral by boiling the total unignited silica for some time in a concentrated solution of sodium carbonate. In the previous analysis I found total SiO_2, 32·32 per cent., and gangue 9·22 per cent. I am inclined to believe that the second determination of the gangue is the more correct of the two, chiefly because larger quantities were used and the treatment with sodic carbonate could be made more thorough. This gangue, obtained as residue insoluble in sodic carbonate solution and afterwards ignited with the filter and weighed, was examined microscopically with the polariscope and an interposed selenite plate. It was found to contain a very considerable proportion of unmistakable free quartz, much of which polarized very distinctly.

The remaining parts of the full analysis of this sample of the mineral have not yet been completed.

REPORT OF THE COMMITTEE ON SCIENCE AND THE ARTS ON THE FOWLER CLOTH CUTTING MACHINE.

HALL OF THE FRANKLIN INSTITUTE,
Philadelphia, April 3, 1882.

The Sub-Committee of the Committee on Science and the Arts, constituted by the Franklin Institute of the State of Pennsylvania, to whom was referred for examination Wm. R. Fowler's Cloth Cutting Machine, report that (at a meeting held on Monday evening, March 27, 1882, at the Institute, at which a majority of the members of the committee were present) they carefully examined a working model of the Fowler Machine, and find that the following claims are worthy of merit, *e. g.:*

The "cutters" or more properly the cutting knives, both the single and double.

The cutting bed.

The work holding device.

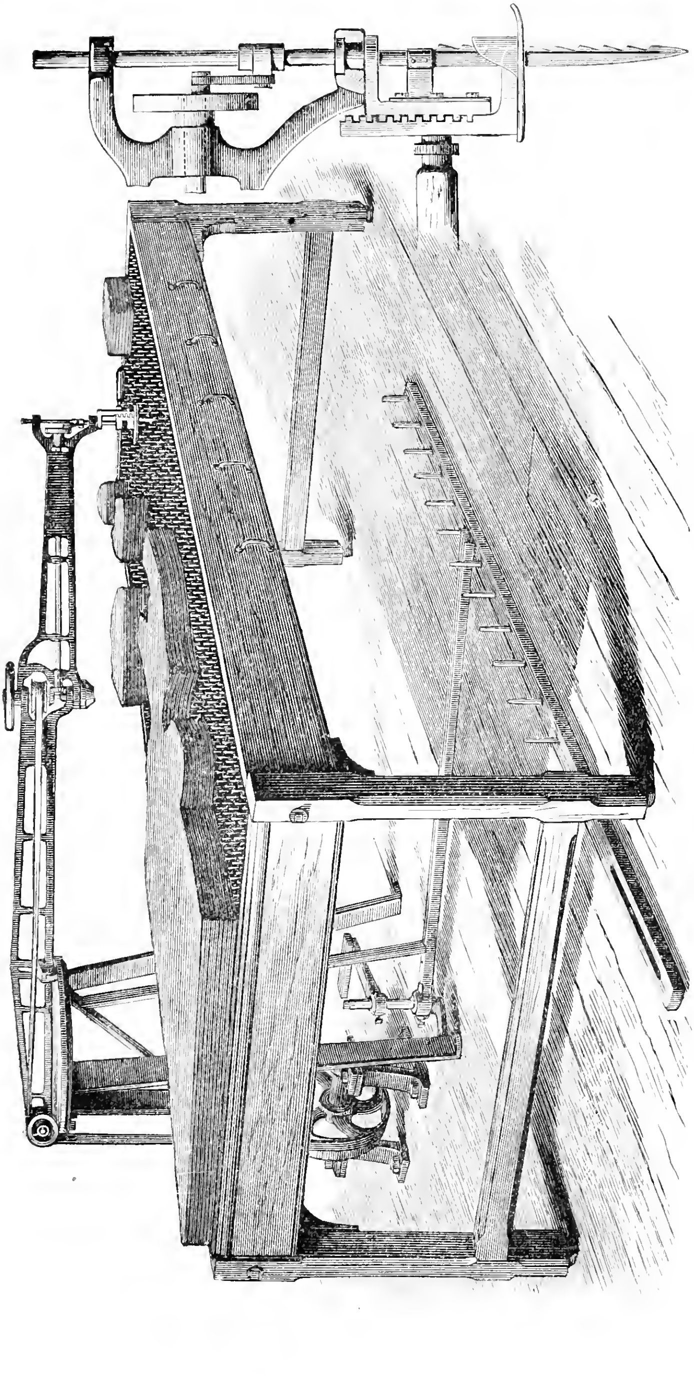
1st. The cutters are made either single or double, having a single cutting edge, or several of these edges, so sharpened as to cut *only* upon the *up-stroke*, having the portion below the said edge reduced in width, or tapered, so as to present a narrow tongue at or near the lower end of the blade, thus forming a strong, durable cutter; the blunt lower end projects beyond the cutting edge, thus protecting it. The series of projections or sharpened edges of the double knife recede from the lower to the upper portion of the knife in step-like form.

The knives when working make 1500 strokes per minute and are made long enough to cut through 4 inches of cloth, and perform their work well.

The knives can be easily ground.

2d. The cutting bed consists of steel wires of sufficient length, set into "blocks" at regular intervals apart, and secured to a backing; the upper ends of wires rounded off. The regular spaces between the wires permit the traversing of the knife in accordance with any pattern marked upon the cloth. From the elasticity of the wires the knife cannot catch upon them, the blunt edge of the knife coming in contact with the wire, slips to one side by bending the wire slightly out of normal position.

This "sectional" bed is inclosed in a rectangular frame resting upon



FOWLER CLOTH CUTTING MACHINE.

four or more legs, to which are attached rollers; this arrangement permits the work-table to be drawn towards the operator when the arm of the machine is fully extended.

The work holding device, in connection with the knife guide, abutment plate of skeleton form, are placed above, upon the work, the knife guide in the general class of cloth cutters being placed underneath the work. This arrangement *above* is a new feature in this class of machines, and the advantages are apparent.

The general arrangement of the working parts of the machine is excellent. The idea of making it light in weight, but strong, is well carried out; the balancing of the arm good; the various parts are nicely fitted, and the machine works easily and performs its work very well indeed.

In furtherance of the above, your committee state that they recommend the award of a Diploma of Merit to Mr. Wm. R. Fowler for his cloth cutting machine, for ingenuity in design and originality.

The above report was adopted at the stated meeting of the Committee on Science and the Arts held June 7, 1882.

WILLIAM H. WAHL, *Secretary.*

Reversals of Temperature.—M. Alluard records several comparative observations in January and February, 1882, at the summit of Puy de Dome and at Clermont, which show that whenever an area of high pressure covers Central Europe, and especially France, it is attended by an inversion of temperature with increase of altitude. Arago observed such an inversion in 1839, and the phenomenon has often been noticed subsequently. The visibility of Mont Blanc from the Puy de Dome furnishes a means of studying the distribution of densities in the lower layers of the atmosphere, especially at epochs of the phenomenon in question. Faye proposes to institute observations upon geodesic refraction, between the summits of the Puy de Dome and certain points which are easily accessible upon Mont Blanc. The beautiful geodesic operations of the French War Department, under the direction of Col. Perier in connection with Spanish officers, show that it would be possible to institute reciprocal and simultaneous measurements of zenith distance between luminous signals upon the two mountains.—*Comptes Rendus*, xciv, 1175. C.

Cause of Scintillation.—Jamin attributes scintillation to the continually changing curvature of the surfaces of luminous waves. He has lately made an extended series of observations with Arago's scintillometer, which confirms the theory of Cooke, Newton and Young, while they discredit that of Arago, who attributed the phenomenon to the interference of waves.—*Les Mondes.* C.

Theory of Rapid Navigation.—Pictet has communicated to the French Academy a summary of the mathematical principles upon which he is constructing his experimental boat. The essential conditions are the following: 1. The volume, of which the equation $F(x, y, z)$ is the exterior surface below the water line, must be equal to the tonnage, T. 2. The integral of the elementary surface multiplied by the sine of the angle, which is made by the element of surface with the axis of translation, must be a minimum. 3. The resultant of the mechanical action of the water against the keel must be a maximum in the direction which is opposed to gravity and a minimum in all other directions. 4. The motive power must be calculated so that its efficient force may be superior to the integral of the resistance of the water for the least velocity which is desired.—*Comptes Rendus.* C.

French Observatories.—The French government, together with the city of Paris, has voted appropriations and given ground for enlarging the operations of the city observatory. The streets which have been opened in the neighborhood have caused the erection of numerous buildings, which threaten to shut out a considerable portion of the horizon, and thus interfere seriously with the work of the observatory. M. Wolf has called the attention of the authorities to these matters, but it seems doubtful whether any effectual remedy can be devised. The new observatory of the Pic du Midi has been completed, and all the instruments have been removed from the old stations, which have been occupied for seven successive winters. A covered subterranean passageway has been built between the dwelling and the platform for the instruments, in which there is a work-shop, a stable and storehouses, together with provisions for various underground observations. A subterranean telegraphic cable has been carried to the summit, which has worked without any interruption by the storms to which the peak is subject. The extent of view, together with the purity and transparency of the air, are likely to make the observatory a very valuable one.—*Gironde.* C.

The Coming Transit of Venus.—A conference of thirty distinguished astronomers, from various parts of the world, has been lately held in Paris, under the presidency of J. B. Dumas, perpetual Secretary of the French Academy. Eight stations of observation were selected; methods of observation were decided, upon and regulations established for the observation of contacts. Before separating, the conference expressed a wish that the French government would come to a definite understanding with other governments for the creation of a temporary international bureau, in order that the results of the observations may be made known as speedily as possible.—*Les Mondes*. C.

Photographs of Flying Birds.—M. Marey has succeeded by instantaneous photography and with the help of a photographic revolver similar to the one which was contrived by Jansen for observing the transit of Venus in obtaining a complete analysis of different forms of locomotion, including the flight of birds. More than two years ago, Muybridge obtained fine pictures of running horses which were photographed in $\frac{1}{500}$ part of a second. He also photographed flying pigeons, but could only get a single picture. Marey has been able to obtain a dozen successive pictures in a second, each exposure requiring only $\frac{1}{700}$ of a second. By arranging the pictures in a phenakistiscope the appearance of the flying bird may be reproduced, under conditions which permit the analysis of different phases of the wings.—*Chron. Industr.* C.

Effects of Cold upon Chrysales.—M. Colasanti has tried the influence of cold upon butterflies and their chrysales. He submitted cocoons, for forty-eight hours, to a temperature of —12° (9·°4F.), so that they were entirely frozen. Then he kept them in a chamber at the ordinary temperature, and the butterflies came out at the proper time, perfectly organized. He afterwards submitted the butterflies themselves to the same temperature. At the end of five minutes they had fallen into a lethargy and soon afterwards they were frozen and stiff as a bit of ice. Those which were weakest were the first to feel the effects of cold. Within ten or fifteen minutes after they had been withdrawn from the low temperature they resumed their normal functions. He subjected the same butterflies to the same degree of cold at three different times, with similar results, but they became gradually more feeble, and they would probably have died if the experiment had been often repeated.—*Les Mondes*. C.

A New Wheel.—Signor Gaetano Contro has invented a new carriage-wheel, in which the iron rim is united to the hub by semicircular steel spokes. The curvature allows them to serve both as spokes and as springs. The result of experimental trials is said to have surpassed the anticipations of the inventor. In great speed, especially, the irregularities of the soil produce no shock. Elasticity, solidity, and complete absence of noise are enumerated among the special advantages of the new invention.—*Les Mondes.* C.

Use of Electricity in Laboratories.—The halls of the five laboratories of the Scientific School at Aix la Chapelle are heated by air, and the temperature is regulated by electric thermometers which transmit automatic signals to the heater: *too cold*, when the temperature is below 17° (62·6° F.); *too warm*, when it exceeds 19° (66·2° F.). The absence of the care-taker has been provided for by call bells, which are operated at the same time as the indicators The great amphitheatre can be lighted either by gas or by the electric light from a Siemens' machine. On removing a panel, behind the Professor's table, a ground glass is exposed which facilitates the use of the electric light for projecting chemical or physical experiments. A quantity machine is employed for electrolytic precipitations. Conductors bring the currents into the laboratory of quantitative analysis and into the the grand amphitheatre.—*D'Electricien*, iii, 47. C.

New Map of the Milky Way.—M. Faye commends the new map of the milky way which has been published in the annals of the Brussels observatory by means of curves of equal luminous intensity. The path forms an almost perfect great circle of the celestial sphere and all the brightest stars, as well as those which are telescopic, appear to be concentrated towards it. The solar system is situated almost exactly in its plane and probably near its centre. The map has the merit of extending to the stars which are visible to the naked eye the results which had already been obtained by Struve for the telescopic stars, and of clearing up in a remarkable manner the present confused notions about the milky way. It seems desirable to calculate the galactic coordinates of the stars and nebulæ as well as their circular variations. The annals give a catalogue of 76 determinations of the sun's parallax, extending over a period of 21 centuries. The mean of the 55 most recent determinations 8.″82, which is precisely the result that Faye had obtained from nine independent methods.—*Comptes Rendus.* C.

Rotary Electric Coefficients of Metals.—Dr. E. H. Hall, of Baltimore, communicated a paper to the British Association upon his electric discovery, giving calculations of the degree of rotation produced by a unit of section of various substances; some of the rotations being positive, others negative. Sir Wm. Thompson regarded the communication as the most important that has been made to electrical science since the days of Faraday. It would be interesting, in view of the nature of electricity and of the properties of matter, to know whether there is a direct action of the magnetism upon the current, or whether the action is upon the distribution of the material molecules, changing the molecular constitution and thus changing the conditions of the propagation of the current.—*L'Electricien.* C.

Metallic Cæsium and Rubidium.—The discovery of cæsium and rubidium was one of the first triumphs of spectrum analysis. They are the most electro-positive of all the known elements; their affinity for oxygen is so great that it has hitherto been impossible to obtain cæsium in the metallic state. The problem, however, has just been resolved by M. Lettenberg by the electrolysis of a melted mixture of cyanide of cæsium and cyanide of barium, of which the experimenter obtained a large quantity at an enormous price. Cæsium is like the other alkaline metals, of a silvery whiteness, very soft and very ductile. Its melting point is 25·°3 (77·°54 F.), and its specific gravity 1·88. It inflames spontaneously in the air, and when thrown upon water it behaves like sodium, potassium and rubidium.—*Les Mondes.* C.

Pompeian Surgery.—Every one who has visited the ruins of Pompeii knows the house of the surgeon, and has heard of the numerous surgical instruments which were found in it at the moment of excavation. Nearly every instrument is now in use, especially in country practice. When we remember that Pompeii was not a city of the first class, but a simple municipality, a borough of small importance in comparison with Naples, it seems remarkable that the Pompeian surgery should have been as thorough and as scientific as it is at the present day in French towns of similar magnitude. The fact is perhaps partly attributable to the influence of the neighboring schools of Magna Græcia, and yet whenever chance permits us, as at Pompeii, to spend a day with men of a former age there is always occasion for surprise that so little change has been made in the most important details of domestic life.—*Les Mondes.* C.

Has the Earth a Fluid Nucleus.—F. Folie proposes an astronomical criterion for settling the question whether any portion of the interior of the globe is fluid. He finds that Laplace and Poisson have entirely neglected, in their integrations, certain terms which have a period of a day or of a fraction of a day. These terms would lead to a diurnal nutation, which could be approximately calculated if there is any considerable portion of melted matter about the centre of the earth. Supposing that hypothesis to be true, the determination of the right ascension of stars which are situated as near as possible to the poles should give different values at different hours of the day, especially at epochs when the longitude of the sun and moon is 90°. Folie invites the attention of astronomers to this subject, especially of those who have a good altazimuth, which will enable them to follow the movement of a star and to make precise determination of its position at every quarter of an hour in its diurnal revolution.—*Bull. de l'Acad. de Belg.* C.

Magnetic Purification of Porcelain Paste.—There is a difference in commercial value of 40 per cent. between pieces of porcelain which are absolutely white and those which present the slightest spot. The spots are produced by small quantities of ferruginous matter, of which the chemical composition is not well known, but which can be attracted by a magnet. Many attempts have been made to use magnets systematically, but they have hitherto been unsuccessful. Two French etablishments have lately employed the following method with very satisfactory results. Each electro-magnet is composed of two coils placed in a line; their remote ends are connected by a long piece of iron; the two near ends are but a short distance apart, one representing the north pole and the other the south pole of the electro-magnet; between them there is a magnetic field which can be made very powerful, provided there is a sufficient exciting current. A tight box encloses this magnetic field; it is open above, and has a round opening below into which an escaping tube is inserted. The porcelain paste, very liquid, running into the box, encounters a small zinc diaphragm which sends it to the right and to the left over the polar faces; the magnetic particles are retained and the rest escapes. The polar surfaces are cleansed twice a day by a jet of water. The apparatus may be worked either with a Gramme machine or with a battery.—*L'Electricien.* C.

Franklin Institute.

Hall of the Institute, September 20, 1882.

The stated meeting of the Institute was held this evening at the usual hour, with the President, Mr. Wm. P. Tatham, in the chair.

The minutes of the last meeting were read and approved.

The Actuary submitted the minutes of the Board of Managers, and reported that since the last meeting of the Institute 12 persons had been elected members. He likewise reported the action of the Board in reference to the death of Mr. Robert Briggs.

The President, after an allusion to Mr. Briggs' long and active connection with the Institute, suggested the propriety of appointing a committee to prepare a suitable memorial.

A motion to this effect was made and carried.

The Committee on Meetings, to whom had been referred the subject of the revision of the order of business, reported progress.

The Special Committee on "Fires in Theatres" reported progress and was continued.

The Special Committee on "Patent Legislation," through Mr. Thos. Shaw, the Chairman, made a report, which was signed by a majority of the committee.

On motion of Mr. Burk the report was adopted and the committee was discharged with the thanks of the Institute.

Mr. William E. Lockwood then read a paper "On the Shaw Locomotive," illustrating the same by means of a model engine, specimens and models of various parts of the mechanism, and numerous lantern slides. The paper was attentively listened to, and provoked a lengthy discussion, which was participated in by Messrs. Strong, Shaw, Burk, Cooper, Cox, Whitney and the author. Mr. John W. Cloud, of Altoona, gave, by invitation, some interesting explanations of theoretical and practical points bearing on the subject.

The Secretary's report embraced a brief *résumé* of the proceedings of the American and British Associations for the Advancement of Science; a description of the application of the Secondary Battery to the lighting of cars of the Pennsylvania Railroad Co.; of the progress of the Hudson River Tunnel, and a description, with lantern illustra-

tions and model, of the Cable System of Street Railways, with especial reference to the cable road now in course of construction on the Columbia avenue extension of the Union Passenger Railway Co.

An invitation was extended to members to visit the officers of the Levett-Müller Electric Light Co., 1003 Chestnut street, on Thursday evening, September 21st, to inspect the operation of the system and to witness the working of a magnetic ore separator.

The following mechanical inventions were shown and described: Ives' Improved Ether-Oxygen Apparatus for the Lantern, in which the hydrogen element is furnished to the blowpipe by dividing the oxygen supply and passing a portion of it through ether, so that it becomes saturated with ether vapor; the mixture burns like hydrogen or coal gas, and the flame is brought to a focus by admitting some oxygen in the usual manner. The saturater has a cotton filling which absorbs the ether, so that none will spill into the tube if it is upset.

The Cumming Periphery-Contact Disc Electrodes consist of two wheels used as electrodes or contact points placed at right angles to each other and impinging on their peripheries. The size of the contact is a mere dot, which is still further reduced by each wheel having a rounded edge consisting of a platinum wire rim run into a groove in the periphery of a brass wheel. The invention is applicable to a great variety of electrical machinery.

A Water Gauge Reflector for Steam Boilers was shown, consisting of a highly polished metallic mirror placed behind and partly surrounding the usual water gauge. It enables the attendant to see the height of water in his gauge glass clearly even in a comparatively dark room.

Specimen Water Meters, manufactured by the Union Water Meter Co., Worcester, Mass., and by the National Water Meter Co., New York, were shown, as were also the Atwood Safety Nut, and the Harvey Manufacturing Co.'s Spiral Wedge, or self-fitting nut.

The President announced that he had appointed Messrs. Henry G. Morris (chairman), B. C. Tilghman, and Henry R. Towne to serve as a committee to prepare a memorial of Mr. Briggs.

Upon which the meeting was adjourned.

WILLIAM H. WAHL, *Secretary*.

List of Books Added to the Library during July, August and September, 1882.

Agriculture of Pennsylvania. Reports for 1881. Harrisburg.
Presented by Hon. G. W. Hall.

American Iron and Steel Association. Annual report of Secretary for 1881. Philadelphia.
Presented by the Association.

Apprentices' Library Company. Philadelphia. Sixty-second Annual Report of the Managers for 1882.
Presented by the Company.

Auditor-General's Report on the Finances of Pennsylvania for 1881. Harrisburg.
Presented by Hon. G. W. Hall.

Births, Marriages and Deaths in Michigan for the year 1876. Tenth Report. Lansing.
Presented by H. B. Baker, Superintendent.

British Association for the Advancement of Science. Report for 1881.
Presented by the Association.

Census Bureau, United States. Statistics of Power and Machinery employed in Manufactures. Washington.
Presented by the Bureau.

Cotton Exposition at Atlanta. 1881. Report.

Couche M. Ch. Voie Matériel Roulant et Exploitation technique des Chemins de Fer. Text and Plates. Paris. 1867—1876.

Dictionarium manuale Latina–Hispanum ad usum puerorummatriti. 1882.
Presented by L. S. Ware.

Encyclopædia Britannica. Vol. 14. Boston. 1882.

Engine, Boiler and Employers' Liability Insurance Company. Engineer's Report for 1882.
Presented by the Company.

Engineer Department, U. S. A. Annual Report of the Chief for 1881. Washington.
Presented by the Department

Frazer, P. Thèses presentées a la Faculté des Sciences de Lille pour obtenir le grade de Docteur ès—Sciences Naturelles.
Presented by the Author.

Gauchez, W. V. Conferences sur l'application du Mouvement de la Mer. Bruxelles. 1881.
Presented by the Minister of War.

Gilbert, F. Life of J. Wood. Chicago. 1882.
Presented by the Author.

Health Bulletins issued by Supervising Surgeon-General. Reprint. Washington. 1881.
Presented by the Supervising Surgeon-General.

Hering, R. System of Main Sewerage for City of Cleveland. 1882.
Presented by the Author.

Hoernes, R. und Auinger, M. Die Gasteropoden. Wien. 1882.
Presented by the K. K. Geol. Reichsanstalt.

Industrial Exhibitions. Cincinnati. Reports of the Ninth and Tenth. 1881—1882.
Presented by W. H. Stewart.

Institution of Civil Engineers of Ireland. Vol. 13. Dublin. 1882.
Presented by the Institution.

Institution of Civil Engineers. Proceedings. Vol. 68. London.
Presented by the Institution.

Internal Affairs of Pennsylvania. Annual Report of the Secretary. Parts 1—4. Harrisburg. 1881.
Presented by the Hon. G. W. Hall.

Interior Department. Contributions to North American Ethnology. Vol. 4. Washington.
Presented by the Department.

Meteorological Charter for the Ocean District adjacent to the Cape of Good Hope.
Presented by the Royal Society.

Meteorological Department of India. Report on the Administration. 1880—1881.
Presented by the Government of India.

Meteorological Observations recorded at Six Stations in India, in 1880—1881.
Presented by the Meteorological Office.

Meteorology of India. Report for 1879.
Presented by the Government of India.

National Board of Health. Annual Report for 1879.
Presented by the Board.

Navy Department. Annual Report of the Secretary for 1881. Washington.
Presented by the Department.

Navy Department. Sanitary and Statistical Report of the Surgeon-General for 1880. Washington.
Presented by the Surgeon-General.

New Jersey. Geological Survey. Annual report of the State Geologist for 1881.
From the State Geologist.

New York State Survey. Report of Director for 1880.
Presented by the Director.

Patent office, French. Brevets d'Invention. Vols. 100, and (U. S.) 22. Paris, 1882. Presented by the Minister of Agriculture, etc.

Patent Office, United States. Specifications and Drawings of Patents granted during October and November, 1882. Washington, 1882. From the Patent Office.

Pennsylvania Railroad Co. Thirty-fifth Annual Report of the Board of Directors. 1882. Presented by the Secretary.

Pennsylvania. Report of the State Treasurer for 1881. Harrisburg. Presented by Hon. G. W. Hall.

Public Instruction in Pennsylvania. Report of the Superintendent for 1881. Harrisburg. Presented by Hon. G. W Hall.

Revue General de l'Architecture et des Travaux Publics. 1877–1881. Presented by Ducher & Cie, Paris.

Royal Cornwall Polytechnic Society. Report for 1881. Presented by the Society.

Science Department. University of Tokio. Memoirs. Nos. 6–8. Presented by the University.

Signal Service. U. S. Annual Report of the Chief for 1879. Washington. Presented by the Chief Signal Officer.

Signal Service, U. S. Professional Papers. Nos. 2, 3, 5, and 6. Washington, 1881–2. Presented by the Chief Signal Officer.

Smith, W. Popular Industrial Art Education. Boston, 1882. Presented by the Author.

Society of Engineers. Transactions for 1881, London. Presented by the Society.

Stereotyping and Electrotyping Machinery. Catalogue, 1881. Presented by R. Hoe & Co.

Treasury Department. Report of Superintendent U. S. Coast Survey for 1878 and 1879. Washington. Presented by the Survey Office.

United States Commission of Fish and Fisheries. Part 7. Report for 1879. Washington. Presented by the Commissioner.

War Department. Annual Report of Secretary for 1880. Washington. Presented by the Department.

JOURNAL

OF THE

FRANKLIN INSTITUTE.

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXIV. NOVEMBER, 1882. No. 5.

AN IMPROVED FEED-WATER HEATER AND PURIFIER.

By GEORGE S. STRONG.

[A paper read at the Stated Meeting of the Franklin Institute, June 21, 1882.]

In order to properly understand the requirements of an effective feed-water purifier it will be necessary to understand something of the character of the impurities of natural waters used for feeding boilers, and of the manner in which they become troublesome in causing incrustation or scale, as it is commonly called, in steam boilers. All natural waters are known to contain more or less mineral matter, partly held in solution and partly in mechanical suspension. These mineral impurities are derived by contact of the water with the earth's surface, and by percolation through its soil and rocks. The substances taken up in solution by this process consist chiefly of the carbonates and sulphates of lime and magnesia, and the chloride of sodium. The materials carried in mechanical suspension are clay, sand and vegetable matter. There are many other saline ingredients in various natural waters, but they exist in such minute quantities, and are generally so very soluble, that their presence may safely be ignored in treating of the utility of boiler waters.

Of the above named salts the carbonates of lime and magnesia are soluble only when the water contains free carbonic acid.

Our American rivers contain from 2 to 6 grains of saline matter to the gallon in solution, and a varying quantity—generally exceeding 10 grains to the gallon—in mechanical suspension. The waters of wells and springs hold a smaller quantity in suspension, but generally carry a larger percentage of dissolved salts in solution, varying from 10 to 650 grains to the gallon.

When waters, containing the carbonates of lime and magnesia in solution, are boiled, the carbonic acid is driven off, and the salts, deprived of their solvent, are rapidly precipitated in fine crystalline particles, which adhere tenaciously to whatever surface they fall upon. With respect to the sulphate of lime the case is different. It is at best only sparingly soluble in water, one part (by weight) of the salt requiring nearly 500 parts of water to dissolve it. As the water evaporates in the boiler, however, a point is soon reached where supersaturation occurs, as the water freshly fed into it constantly brings fresh accessions of the salt; and when this point is reached the sulphate of lime is precipitated in the same form and with the same tenaciously adherent quality as the carbonates. There is, however, a peculiar property possessed by this salt which facilitates its precipitation, namely, that its solubility in water diminishes as the temperature rises. This fact is of special interest, since, if properly taken advantage of, it is possible to effect its almost complete removal from the feed-water of boilers.

There is little difference in the solubility of the sulphate of lime until the temperature has risen somewhat above 212°Fahr., when it rapidly diminishes, and finally, at nearly 300°, all of this salt held in solution at lower temperatures, will be precipitated when the temperature had risen to that point. The following table* represents the

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* *Vide* Burgh, Modern Marine Engineering, page 176 *et. seq.* M. Consté, *Annales des Mines*, v, 69. *Recherches sur l'incrustation des Chaudieres à vapeur.* Mr. Hugh Lee Pattison, of Newcastle-on-Tyne, at the meeting of the Institute of Mechanical Engineers of Great Britain, in August, 1880, remarked on this subject, that "The solubility of sulphate of lime in water diminishes as the temperature rises. At ordinary temperatures pure water dissolves about 150 grains of sulphate of lime per gallon; but at a temperature of 255° Fahr., at which the pressure of steam is equal to about 2 atmospheres, only about 40 grains per gallon are held in solution. At a pressure of 3 atmospheres, and temperature of 302° Fahr., it is practically insoluble. The point of maximum solubility is about 95° Fahr. The presence of magnesium chloride, or of calcium chloride, in water, diminishes its power of dissolving sulphate of lime, while the presence of sodium chloride increases that power. As an instance of the latter fact, we find a boiler works much cleaner which is fed alternately with fresh water and with brackish water pumped from the Tyne when the tide is high than one which is fed with fresh water constantly."

solubility of sulphate of lime in sea water at different temperatures:

Temperature Fahr.	Percentage Sulph. Lime held in Solution.
217°	0·500
219°	0·477
221°	0·432
227°	0·395
232°	0·355
236°	0·310
240°	0·267
245°	0·226
250°	0·183
255°	0·140
261°	0·097
266°	0·060
271°	0·023
290°	0·000

These figures hold substantially for fresh as well as for sea water, for the sulphate of lime becomes wholly insoluble in sea water, or in soft water, at temperatures comprised between 280° and 300° Fahr.

It appears from this that it is simply necessary to heat water up to a temperature of 250° in order to effect the precipitation of four-fifths of the sulphate of lime it may have contained, or to the temperature of 290° in order to precipitate it entirely. The bearing of these facts on the purification of feed-waters will appear further on. The explanation offered to account for the gradually increasing insolubility of sulphate of lime on heating, is, that the hydrate, in which condition it exists in solution, is partially decomposed, anhydrous calcic sulphate being formed, the dehydration becoming more and more complete as the temperature rises. Sulphate of magnesia, chloride of sodium (common salt), and all the other more soluble salts contained in natural waters are likewise precipitated by the process of supersaturation, but owing to their extreme solubility their precipitation will never be effected in boilers; all mechanically suspended matter tends naturally to subside.

Where water containing such mineral and suspended matter is fed to a steam boiler there results a combined deposit, of which the carbonate of lime usually forms the greater part, and which remains more or less firmly adherent to the inner surfaces of the boiler, undisturbed by the force of the boiling currents. Gradually accumulating, it becomes

harder and thicker, and if permitted to accumulate, may at length attain such thickness as to prevent the proper heating of the water by any fire that may be maintained in the furnace. Dr. Joseph G. Rogers, who has made boiler waters and incrustations a subject of careful study, declares that the high heats necessary to heat water through thick scale will sometimes actually convert the scale into a species of glass, by combining the sand, mechanically separated, with the alkaline salts. The same authority has carefully estimated the non-conducting properties of such boiler incrustations. On this point he remarks that the evil effects of the scale are due to the fact that it is relatively a non-conductor of heat. As compared with iron its conducting power is as 1 to $37\frac{1}{2}$, consequently more fuel is required to heat water in an incrusted boiler than in the same boiler if clean. Rogers estimates that a scale 1-16th of an inch thick will require the extra expenditure of 15 per cent. more fuel, and this ratio increases as the scale grows thicker. Thus, when it is one-quarter of an inch thick, 60 per cent. more fuel is needed; one-half inch, 112 per cent. more fuel, and so on.

Rogers very forcibly shows the evil consequences to the boiler from the excessive heating required to raise steam in a badly incrusted boiler, by the following illustration: To raise steam to a pressure of 90 pounds the water must be heated to about 320° Fahr. In a clean boiler of one-quarter inch iron this may be done by heating the external surface of the shell to about 325° Fahr. If now one-half an inch of scale intervenes between the boiler shell and the water, such is its quality of resisting the passage of heat that it will be necessary to heat the fire surface to about 700°, almost to a low red heat, to effect the same result. Now the higher the temperature at which iron is kept the more rapidly it oxidizes, and at any heat above 600° it very soon becomes granular and brittle, and is liable to bulge, crack or otherwise give way to the internal pressure. This condition predisposes the boiler to explosion and makes expensive repairs necessary. The presence of such scale, also, renders more difficult the raising, maintaining and lowering of steam.

The nature of incrustation and the evils resulting therefrom having been stated, it now remains to consider the methods that have been devised to overcome them. These methods naturally resolve themselves into two kinds, chemical and mechanical. The chemical method has two modifications; in one the design is to purify the water in large tanks or reservoirs, by the addition of certain substances which shall

precipitate all the scale-forming ingredients before the water is fed into the boiler; in the other the chemical agent is fed into the boiler from time to time and the object is to effect the precipitation of the saline matter in such a manner that it will not form solid masses of adherent scale. Where chemical methods of purification are resorted to the latter plan is generally followed as being the least troublesome. Of the many substances used for this purpose, however, some are measurably successful; the majority of them are unsatisfactory or objectionable.

The mechanical methods are also very various. Picking, scraping, cleaning, etc., are very generally resorted to, but the scale is so tenacious that this only partially succeeds, and as it necessitates stoppage of work, it is wasteful. In addition to this plan, a great variety of mechanical contrivances for heating and purifying the feed-water, by separating and intercepting the saline matter on its passage through the apparatus, have been devised. Many of these are of great utility and have come into very general use. In the Western States especially, where the water in most localities is heavily charged with lime, these mechanical purifiers have become quite indispensable wherever steam users are alive to the necessity of generating steam with economy.

Most of these appliances, however, only partly fulfill their intended purposes. They consist essentially of a chamber through which the feed-water is passed, and in which it is heated almost to the boiling point by exhaust steam from the engine. According to the temperature to which the water is heated in this chamber, and the length of time required for its passage through the chamber, the carbonates are more or less completely precipitated, as likewise the matter held in mechanical suspension. The precipitated matter subsides on shelves or elsewhere in the chamber, from which it is removed from time to time. The sulphate of lime, however, and the other soluble salts, and in some cases also a portion of the carbonates that were not precipitated during the brief time of passage through the heater, are passed on into the boiler.

Appreciating this insufficiency of existing feed-water purifiers to effectually remove these dangerous saline impurities, the writer in designing the feed water heater now to be described paid special attention to the separation of all matters, soluble and insoluble; and he has succeeded in passing the water to the boilers quite free from any substance which would cause scaling or coherent deposit. His attention was more particularly called to the necessity of extreme care in this

respect, through the great annoyance suffered by steam users in the Central and Western States, where the water is heavily charged with lime. Very simple and even primitive boilers are here used; the most necessary consideration being handiness in cleaning, and not the highest evaporative efficiency. These boilers are therefore very wasteful, only evaporating, when covered with lime scale, from two to three pounds of water with one pound of the best coal, and requiring cleansing once a week at the very least. The writer's interest being aroused, he determined, if possible, to remedy these inconveniences, and accordingly he made a careful study of the subject, and examined all the heaters then in the market. He found them all, without exception, insufficient to free the feed-water from the most dangerous of impurities, namely, the sulphate and the carbonate of lime.

Taking the foregoing facts, well known to chemists and engineers, as the basis of his operations, the writer perceived that all substances likely to give trouble by deposition would be precipitated at a temperature of about 250° F.

His plan was, therefore, to make a feed-water heater in which the water could be raised to that temperature before entering the boiler. Now, by using the heat from the exhaust steam the water may be raised to between 208° and 212° F. It has yet to be raised to 250° F.; and for this purpose the writer saw at once the advantage that would be attained by using a coil of live steam from the boiler. This device does not cause any loss of steam, except the small loss due to radiation, since the water in any case would have to be heated up to the temperature of the steam on entering the boiler. By adopting this method the chemical precipitation, which would otherwise occur in the boiler, takes place in the heater; and it is only necessary now to provide a filter, which shall prevent anything passing that can possibly cause scale.

Having explained as is briefly as possibly the principles on which the system is founded, the writer will now describe the details of the heater itself.

In Figs. 1 and 2 are shown an elevation and a vertical section of the heater. The cast-iron base, *A*, is divided into two parts by the diaphragm *B*. The exhaust steam enters at *C*, passes up the larger tubes *D*, which are fastened into the upper shell of the casting, returns by the smaller tubes *E*, which are inside the others, and passes away by the passage *F*. The inner tube only serves for discharge. It will be

seen at once that this arrangement, while securing great heating surface in a small space, at the same time leaves freedom for expansion and contraction, without producing strains. The free area for passage of steam is arranged to be one and a half times that of the

Fig. 1.
Elevation.

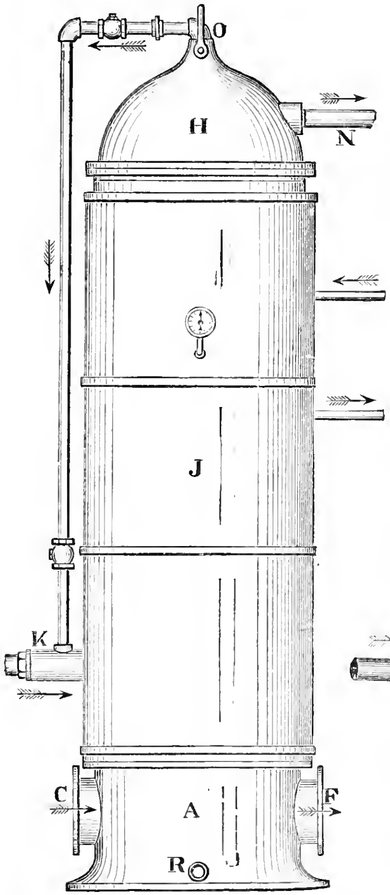
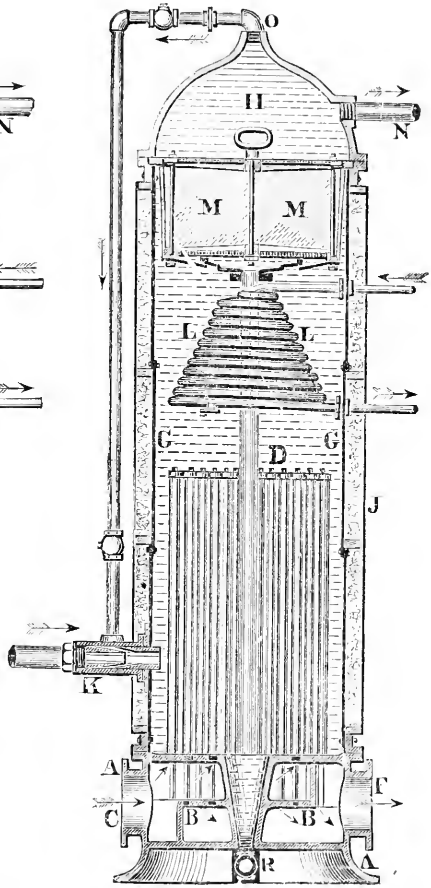


Fig. 2.
Vertical Section.



exhaust pipe, so that there is no possible danger of back pressure. The wrought iron shell *G*, connecting the stand *A* with the dome *H*, is made strong enough to withstand the full boiler pressure. An ordi- casing, *J*, of wood or other material prevents loss by radiation of heat.

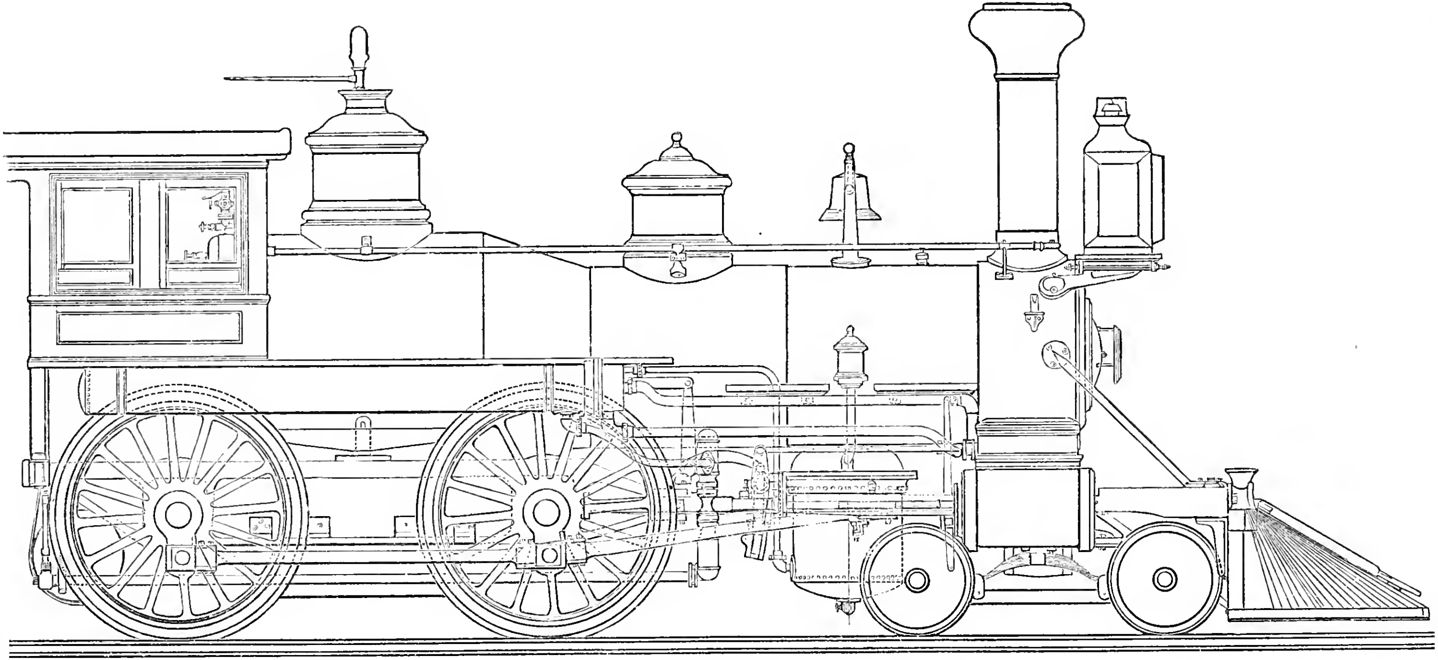


FIG. 3.

The cold water from the pump passes into the heater through the injector arrangement, *K*, and coming in contact with the tubes D is heated; it then rises to the coil *L*, which is supplied with steam from the boiler, and thus becomes further heated, attaining there a temperature of from 250° to 270°F., according to the pressure in the boiler. This high temperature causes the separation of the dissolved salts; and on the way to the boiler the water passes through the filter *M*, becoming thereby freed from all precipitated matter before passing away to the boiler at *N*. The purpose of the injector *K*, and the pipe passing from *O* to *K*, is to cause a continual passage of air or steam from the upper part of the dome to the lower part of the heater, so that any precipitate carried up in froth may be again returned to the under side of the filter, in order more effectually to separate it, before any chance occurs of its passing into the boiler.

The filter consists of wood charcoal in the lower half and bone black above, firmly held between two perforated plates, as shown. After the heater has been in use for from three to ten hours, according to the nature of the water used, it is necessary to blow out the heater, in order to clear the filter from deposit. To do this the cock at *R* is opened, and the water is discharged by the pressure from the boiler. The steam is allowed to pass through the heater for some little time, in order to clear the filter completely. After this operation all is ready to commence work again. By this means the filter remains fit for use for months without change of the charcoal.

Where a jet condenser is used either of two plans may be adopted. One plan takes the feed-water from the hot well and passes the exhaust from the feed pumps through the heater, using at the same time an increased amount of coil for the live steam. By this means a temperature of water is attained high enough to cause deposition, and at the same time to produce decomposition of the oil brought over from the cylinders. The other plan places the heater in the line of exhaust from the engine to the condenser, also using a larger amount of coil. Both these methods work well. The writer sometimes uses the steam from the coil to work the feed pump; or, if the heater stands high enough, it is only necessary to make a connection with the boiler, when the water formed by the condensation of the steam runs back to the boiler, and thus the coil is kept constantly at the necessary temperature.

In adapting the heater to locomotives we were met with the diffi-

culty of want of space to put a heater sufficiently large to handle the extremely large amount of water evaporated on a locomotive worked up to its full capacity, being from 1500 to 2500 gallons per hour, or from five hundred to one thousand HP. We designed various forms of heaters and tried them, but have finally decided on the one shown in the engraving, Fig. 3, which consists of a lap welded tube 13 inches internal diameter, 12 feet long, with a cast-iron head which is divided into two compartments or chambers by a diaphragm. Into this head are screwed sixty tubes, one inch outside diameter and 12 feet long, which are of seamless brass. These are the heating tubes within which are internal tubes for circulation only, which are screwed into the diaphragm and extend to within a very short distance of the end of the heating tube. The exhaust steam for heating is taken equally from both sides of the locomotive by tapping a two-inch nipple with a cup-shaped extension on it in such a way as to catch a portion of the exhaust without interfering with the free escape of the steam for the blast, and without any back pressure, as it relieves the back pressure as much as it condenses. The pipe from one side of the engine is connected with the chamber into which the heating tubes are screwed, and is in direct communication with them. The pipe from the other side is connected with the chamber into which the circulating tubes are screwed. The beat of the exhaust working, as it does, on the quarters causes a constant sawing or backward and forward circulation of steam without any discharge, and only the condensation is carried off.

The water is brought from the pump and discharged into the lower side of the heater well forward, and passes around the heating tubes to the end, when it is discharged into a pipe that carries it forward, either direct to the check or into the purifier, which is located between the frames under the boiler, and consists of a chamber in which are arranged a live steam coil and a filter above the coil. The water coming in contact with the coil, its temperature is increased from the temperature of the exhaust, 210°, to about 250° Fahr., which causes the separation of the lime salts as before described, and it then passes through the filter and direct to the boiler from above the filter, which is cleansed by blowing back through it as before described.

One of these heaters lately tested showed a saving in coal of 22 per cent. and an increase of evaporation of 1·09 pounds of water per pound of coal.

ECONOMICAL STEAM POWER.

By William Barnet Le Van.

[A paper read by title at the Stated Meeting of the Franklin Institute, Oct. 18, 1882.]

The most economical application of steam power can be realized only by a judicious arrangement of the plant: namely, the engines, boilers, and their accessories for transmission.

This may appear a somewhat broad assertion; but it is nevertheless one which is amply justified by facts open to the consideration of all those who choose to seek for them.

While it is true that occasionally a factory, mill, or a water-works may be found in which the whole arrangements have been planned by a competent engineer, yet such is the exception and not the rule, and such examples form but a very small percentage of the whole.

The fact is that but few users of steam power are aware of the numerous items which compose the cost of economical steam power, while a yet smaller number give sufficient consideration to the relations which these items bear to each other, or the manner in which the economy of any given boiler or engine is affected by the circumstances under which it is run.

A large number of persons—and they are those who should know better, too—take for granted that a boiler or engine which is good for one situation is good for all; a greater error than such an assumption can scarcely be imagined.

It is true that there are certain classes of engines and boilers which may be relied upon to give moderately good results in almost any situation—and the best results should *always* be desired in arrangement of a mill—there are a considerable number of details which must be taken into consideration in making a choice of boilers and engines.

Take the case of a mill in which it has been supposed that the motive power could be best exerted by a single engine. The question now is whether or not it would be best to divide the total power required amongst a number of engines.

First. A division of the motive power presents the following

advantages, namely, a saving of expense on lines of shafting of large diameter.

Second. Dispensing with the large driving belt or gearing, the first named of which, in one instance under the writer's observation, absorbed *sixty horse-power* out of about 480, or about *seven per cent.*

Third. The general convenience of subdividing the work to be done, so that in case of a stoppage of one portion of the work by reason of a loose coupling or the changing of a pulley, etc., that portion only would need to be stopped.

This last is of itself a most important point, and demands careful consideration.

For example, I was at a mill a short time ago when the governor belt broke. The result was a stoppage of the whole mill. Had the motive power of this mill been subdivided into a number of small engines only one department would have been stopped. During the stoppage in this case the windows of the mill were a sea of heads of men and women (the operatives), and considerable excitement was caused by the violent blowing off of steam from the safety-valves, due to the stoppage of the steam supply to the engine; and this excitement continued until the cause of the stoppage was understood. Had the power in this mill been subdivided the stoppage of one of a number of engines would scarcely have been noticed, and the blowing off of surplus steam would not have occurred.

In building a mill the first item to be considered is the interest on the first cost of the engine, boilers, etc. This item can be subdivided with advantage into the amounts of interest on the respective costs of,

First. The engine or engines;

Second. The boiler or boilers;

Third. The engine and boiler house.

In the same connection the *form* of engine to be used must be considered. In some few cases—as, for instance, where engines have to be placed in confined situations—the form is practically fixed by the space available, it being perhaps possible only to erect a vertical or a horizontal engine, as the case may be. These, however, are exceptional instances, and in most cases—at all events where large powers are required—the engineer may have a free choice in the matter. Under these circumstances the best form, in the vast majority of cases where machinery must be driven, is undoubtedly the horizontal engine, and the worst the beam engine. When properly constructed, the hori-

zontal engine is more durable than the beam engine, whilst, its first cost being less, it can be driven at a higher speed, and it involves a much smaller outlay for engine house and foundations than the latter. In many respects the horizontal engine is undoubtedly closely approached in advantages by the best forms of vertical engines; but on the whole we consider that where machinery is to be driven the balance of advantages is decidedly in favor of the former class, and particularly so in the case of large powers.

The next point to be decided is, whether a condensing or non-condensing engine should be employed. In settling this question not only the respective first costs of the two classes of engines must be taken into consideration, but also the cost of water and fuel. Excepting, perhaps, in cases of very small powers, and in those instances where the exhaust steam from a non-condensing engine can be turned to good account for heating or drying purposes, it may safely be asserted that in all instances where a sufficient supply of condensing water is available at a moderate cost, the extra economy of a well-constructed condensing engine will fully warrant the additional outlay involved in its purchase. In these days of high steam pressures, a well constructed non-condensing engine can, no doubt, be made to approximate closely to the economy of a condensing engine, but in such a case the extra cost of the stronger boiler required will go far to balance the additional cost of the condensing engine.

Having decided on the form, the next question is, what "class" of engine shall it be; and by the term class I mean the relative excellence of the engine as a power-producing machine. An automatic engine costs more then a plain slide-valve engine, but it will depend upon the cost of fuel at the location where the engine is to be placed, and the number of hours per day it is kept running, to decide which class of machine can be adopted with the greatest economy to the proprietor. The cost of lubricating materials, fuel, repairs, and percentage of cost to be put aside for depreciation, will be less in case of the high-class than in the low-class engine, while the former will also require less boiler power.

Against these advantages are to be set the greater first cost of the automatic engine, and the consequent annual charge due to capital sunk. These several items should all be fairly estimated when an engine is to be bought, and the kind chosen accordingly. Let us take the item of fuel, for instance, and let us suppose this fuel to cost four

dollars per ton at the place where the engine is run. Suppose the engine to be capable of developing one hundred horse-power, and that it consumes five pounds of coal per hour per horse-power and runs ten hours per day: this would necessitate the supply of two and one-half tons per day at a cost of ten dollars per day. To be really economical, therefore, any improvement which would effect a saving one pound of coal per hour per horse-power must not cost a greater sum per horse-power than that on which the cost of the difference of the coal saved (one pound of coal per hour per horse-power, which would be 1000 pounds per day) for say three hundred days, three hundred thousand (300,000) pounds, or one hundred and fifty tons (or six hundred dollars), would pay a fair interest.

Assuming that the mill owner estimates his capital as worth to him ten per cent. per annum, then the improvement which would effect the above mentioned saving must not cost more than six thousand dollars, and so on. If instead of being run only ten hours per day the engine is run night and day, then the outlay which it would be justifiable to make to effect a certain saving per hour would be doubled; while, on the other hand, if an engine is run less than the usual time per day a given saving per hour would justify a correspondingly less outlay.

It has been found that for grain and other elevators, which are not run constantly, gas engines, although costing more for the same power, are cheaper than steam engines for elevating purposes where only occasionally used.

For this reason it is impossible without considerable investigation to say what is really the most economical engine to adopt in any particular case; and as comparatively few users of steam power care to make this investigation a vast amount of wasteful expenditure results. Although, however, no absolute rule can be given, we may state that the number of instances in which an engine which is wasteful of fuel can be used profitably is exceedingly small. As a rule, in fact, it may generally be assumed that an engine employed for driving a manufactory of any kind cannot be of too high a class, the saving effected by the economical working of such engines in the vast majority of cases enormously outweighing the interest on their extra first cost. So few people appear to have a clear idea of the vast importance of economy of fuel in mills and factories that I perhaps cannot better conclude than by giving an example showing the saving to be effected in a large establishment by an economical engine.

I will take the case of a flouring mill in this city which employed two engines that required forty pounds of water to be converted into steam per hour per indicated horse-power. This, at the time, was considered a moderate amount and the engines were considered "good."

These engines indicated seventy horse-power each, and ran twenty-four hours per day on an average of three hundred days each year, requiring as per indicator diagrams forty million three hundred and twenty thousand pounds ($40\times70\times24\times300\times2=40,320,000$) of feed water to be evaporated per annum, which, in Philadelphia, costs three dollars per horse-power per annum, amounting to ($70\times2\times300=\$420.00$), four hundred and twenty dollars.

The coal consumed averaged five and one-half pounds per hour per horse-power, which, at four dollars per ton costs

$$\left(\frac{70\times2\times5{\cdot}5\times24\times300}{2000}\times4.00=\$11,088\right.$$

Eleven thousand and eighty-eight dollars.

Cost of coal for 300 days, ...	\$11,088
Cost of water for 300 days, ...	420
Total cost of coal and water, ...	\$11,508

These engines were replaced by one first-class automatic engine, which developed one hundred and forty-two horse-power per hour with a consumption of *three pounds* of coal per hour per horse-power, and the indicator diagrams showed a consumption of *thirty* pounds of water per hour per horse-power. Coal cost

$$\left(\frac{142\times3\times24\times300}{2000}\times4.00=\$6134\right)$$

Six thousand one hundred and thirty-four dollars. Water cost ($142\times3.00=\$426.00$) four hundred and twenty-six dollars.

Cost of coal for 300 days, ...	\$6,134
Cost of water for 300 days, ...	426
Total cost of coal and water, ...	\$6,560

The water evaporated in the latter case to perform the same work was ($142\times30\times24\times300=30,672,000$), thirty million six hundred and seventy-two thousand pounds of feed water against (40,320,000), forty million three hundred and twenty thousand pounds in the

former, a saving of (9,648,000), nine million six hundred and forty-eight thousand pounds per annum; or,

$$\frac{40,320,000 - 30,672,000}{9,648,000} = 31{\cdot}4 \text{ per cent.}$$

Thirty-one and four-tenths per cent.

And a saving in coal consumption of

$$\frac{11,088 - 6,134}{4954} = 87{\cdot}5 \text{ per cent.}$$

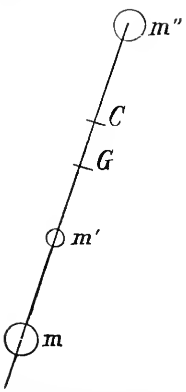
Eighty-seven and one-half per cent., or a saving in dollars and cents of four thousand nine hundred and fifty-four dollars ($4954).

In this city, Philadelphia, no allowance for the consumption of water is made in the case of first-class engines, such engines being charged the same rate per annum per horse-power as an inferior engine, while, as shown by the above example, a saving in water of *thirty-one and four-tenths per cent.* has been attained by the employment of a first-class engine. The builders of such engines will always give a guarantee of their consumption of water, so that the purchaser can be able in advance to estimate this as accurately as he can the amount of fuel he will use.

NOTE ON THE PENDULUM.

By JOHN R. FRENCH, LL.D.
Professor of Mathematics in Syracuse University.

In certain vibrating clocks, the movement is retarded by the elevation of the "bob." Not having been able to find any discussion of the cause of this peculiarity of the pendulum, I present the following:



Let m'' be the mass of that part of the clock above the point of support C, supposed concentrated at the distance r'' of its centre of gravity from C. Let m' be the mass of that part of the clock below C, exclusive of the bob, similarly concentrated at the distance r' from C; and let m be the movable bob, whose distance from C is r. Let l be the length of a simple pendulum, whose vibrations are isochronous with those of the clock.

Then, from the familiar discussion of the compound pendulum ("Peck's Mechanics," p. 171),

$$(m'r' - m''r'' + mr)l = m'r'^2 + m''r''^2 + mr^2 \quad . \quad . \quad (1)$$

If an increment h be given to r, producing a change k in l, this equation becomes

$$(m'r' - m''r'' + m(r + h)(l + k) = m'r'^2 + m''r''^2 + m(r + h)^2 \quad . \quad (2)$$

Subtracting equation (1) from equation (2), we get

$$(m'r' - m''r'' + mr)k + m(hl + hk) = m(2hr + h^2) \quad . \quad (3)$$

If h and k are infinitesimally small, hk and h^2 may be dropped; then dividing equation (3) by hm, we have

$$\frac{m'r' - m''r'' + mr}{m} \cdot \frac{k}{h} + l = 2r \quad . \quad . \quad (4)$$

The first fraction in this equation must always be plus; since, in order to make vibrations possible, the centre of gravity G must be below C. Therefore equation (4) shows

1st. That if h and k are both plus, $r > \frac{1}{2}l$.
2d. That if $+ h$ produces $-k$, $r < \frac{1}{2}l$.
3d. That if, for $\pm h$, $k = o$, $r = \frac{1}{2}l$.

That is to say, if the bob is at a distance from C, the point of support, equal to half the length of a simple isochronous pendulum, a slight elevation or depression will produce no change in the rate of the clock. If it is below this point, its depression retards the vibrations, as in the ordinary clock; but if the bob is above this central point, the usual rule is reversed, viz.: the elevation of the bob retards, and its depression accelerates the motion.

This discussion holds good when $m'' = 0$, which is the case of the common pendulum.

Otherwise—

The moment of the accelerating force exerted by the mass m is ("Peck's Mechanics," *ibid.*):

$$m(l - r)rw,$$

in which w is the angular velocity and is constant for any given position of the pendulum. The varying part of the above expression, depending upon the position of the bob is, therefore,

$$u = lr - r^2,$$

whence

$$\frac{du}{dr} = r\frac{dl}{dr} + l - 2r \quad . \quad . \quad (5)$$

By differentiating equation (1) we deduce

$$\frac{dl}{dr} = \frac{m(2r - l)}{m'r' - m''r'' + mr}$$

which vanishes, for $r = \frac{1}{2}l$.

Omitting, therefore, the first term of the second member of equation (5)

$$\frac{du}{dr} = l - 2r$$

whence du, or the variation in the accelerating force, will be minus, plus, or zero, as r is greater, less than, or equal to $\frac{1}{2}l$, as before.

Syracuse, Sept. 15, 1882.

VISION BY THE LIGHT OF THE ELECTRIC SPARK.*

By W. Le Conte Stevens.

In former papers† the writer has discussed certain phenomena of vision under variable physiological conditions, and criticised the theory of the stereoscope as given in most of the text-books of Physics. While testing the effect of varying the strain upon the muscles of the eyes as a means of modifying the unconscious interpretation put upon the binocular retinal image, he was led to the discovery of a new mode of stereoscopy, in which a pair of absolutely similar pictures, such as a pair of like series of concentric circles on plane cards, are made to yield the binocular effect of convexity, flatness, or concavity, at will, by causing each card to rotate through any desired angle on a vertical axis, so that the two pictures are oppositely inclined to the horizontal visual lines. Since the retinal image is on a curved surface to which the visual line is approximately normal, while the plane of the card is oblique to this line, a circle on the card will be projected as a slightly distorted ellipse upon the retina. Assuming the two visual lines to be parallel and the distance between the centres

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* Abstract of a paper read before the American Association for the Advancement of Science, at the Montreal meeting, August, 1882.

† *Am. Jour. Science*, Nov. and Dec., 1881; March, April and May, 1882; *London Philosophical Magazine*, Dec., 1881, and May, 1882; Journal of the Franklin Institute, May and Oct., 1882.

of the circles on oppositely inclined cards to be equal to the distance between the observer's optic centres, the distortions of the ellipses on the two retinas will be opposite in sense. We have thus slightly different retinal pictures in the two eyes at the same time, and the binocular effect is like that produced by a solid body in space, or by a pair of dissimilar photographs composing an ordinary stereograph.

This will be easily understood on reference to Fig. 1, where O and O' represent the observer's crystalline lenses, OC and $O'C'$ the horizontal visual lines, ED and $E'D'$ the horizontal diameters of a pair of circles on cards whose planes are perpendicular to that of the paper, these cards having been rotated about the vertical axes at C and C'

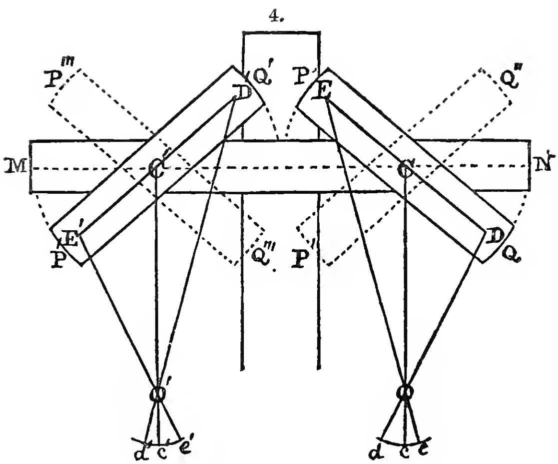

FIG. 1.

from an initial direction, MN, into the two directions, ED and $E'D'$, which are oppositely inclined to OC and $O'C'$. The retinal images, dce and $d'c'e'$, are necessarily unequally divided at c and c', dc being greater than $d'c'$. If the attention be withdrawn from C and C', while binocularly viewing the cards, to D and D', or E and E', the visual lines pass from parallelism into divergence. A slight additional strain is thus imposed upon the external rectus muscles of the eyeballs. The resulting tendency therefore is to make the observer imagine D and D', E and E' to be more remote than C and C'. The binocular image must hence appear convex.

Previous experiments on the visual effects resulting from muscular strain in the eyes suggested at once the explanation just given, on the

hypothesis that the eyes have freedom of motion in examining the pictures thus binocularly viewed. Many persons in making this experiment for the first time fail to attain any clear perception of depth in the binocular image until after the eyes have been directed successively to different parts of the field of view. The conditions are a little unusual and momentary confusion is the result. The writer deemed it worth ascertaining whether the perception of such depth is attainable by momentary illumination of the cards, during which play of the eyes is impossible and hence cannot be considered in explanation of the phenomenon; in other words, whether the explanation already advanced was itself sufficient, or only supplementary to other considerations, though true so far as it goes.

The apparatus employed for illumination was an induction coil, the use of which was granted by Prof. O. N. Rood, of Columbia College, a Leyden jar being interposed in the secondary circuit. The cards were placed upon an attachment, by which rotation could be given them on the arms of the reflecting stereoscope described in a former paper.* The value of the optic angle, the distance of each card, and the angle made by its plane with the corresponding visual line could thus be recorded. The writer secured the co-operation of Mr. W. W. Share, assistant in Physics in Columbia College, each of the two acting alternately as observer and as manipulator of the apparatus.

Arranging the arms of the stereoscope so as to necessitate parallelism of visual lines the observer seated himself, with closed eyes, in proper position, while the manipulator arranged the pair of diagrams so as to produce either concavity, convexity, or planeness in the binocular picture. The room was then darkened, and, on the passing of a spark, the observer was requested to interpret the form of the binocular image, of which he was necessarily previously ignorant. It was found usually possible, on first trial, to secure a correct interpretation, whether the diagrams had been made in such manner as to produce the appearance of relief in the ordinary stereoscope, or whether concentric circles oppositely inclined to the two visual lines were employed. When the arms of the stereoscope were so arranged as to produce slight divergence or strong convergance of visual lines, the proper relation between these by trial required the transmission of more than one spark before the requisite adjustment was secured, but binocular relief became at

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* Journal of the Franklin Institute, October, 1882.

once perceptible, with the same variation in apparent size and distance of the image that had formerly been produced under continuous light. The abnormal conditions, however, made it more difficult to form reliable judgments. A series of such experiments, therefore, was made by Mr. Share and the writer, with results quite similar to those already published.

Knowing the distance of the cards, the diameter of each circle, the angle made by its plane with the visual line, and the distance from nodal point to retina in the observer's eye, and assuming parallel vision, it becomes possible to calculate the degree of distortion of each ellipse as projected on the retina, and thus to calculate the maximum "retinal displacement" that under the given conditions can co-exist with clear binocular vision. If each eye be directed to the centre of the circle in front of it the greatest displacement obviously corresponds to the marginal portions of the binocular image. The unity of the image remained thus apparent when the retinal displacement was more than 3 mm., an interval so far exceeding the estimated *minimum visible* as to preclude retinal fusion. Indeed, by giving the attention, through indirect vision, to these marginal parts without changing the direction of the visual lines, double images were at once detectible, while the perception of relief became less clear. This was observed by both Mr. Share and the writer. On the other hand, experiments were made to ascertain the minimum rotation of the cards that was necessary to change the binocular image from a plane to a perceptibly curved surface. An angle of one degree was found sufficient; the resulting retinal displacement being so small that no double image could be perceived under such circumstances with even the acutest vision thus far tested.

These experiments therefore tend to confirm the conclusion reached by Helmholtz, in opposition to many other physiologists, that neither play of the eyes nor the perception of double images is necessary to the distinctness of binocular vision, however important these elements may sometimes be in confirming our visual judgments, conscious or unconscious. Indeed, the perception of double images requires a special act of attention; and if the production of these is a necessary incident in all binocular vision at short distances—and this is unquestionably true,—the conscious perception of them interferes with the clearness of such vision instead of being a necessity. Each eye transmits its own separate sensation to the brain, and the resultant idea is referred to the external thing, not consciously to the sensation. Many of our judg-

ments, not only in vision but in the performance of other bodily functions, are instantaneous and unconscious; but probably we shall never be able to put an exact dividing line between those due to the experience of the individual and those that spring from tendencies transmitted by the race. If passive seeing be a result of mere inheritance, then active looking is superadded as a result of training. By oft-repeated efforts, which form a succession of experiences, we learn to see, just as we learn to walk or talk in infancy. We may attain the mechanical analysis of walking and even talking, knowing the structure of the organs employed and the relative positions of the various parts. The analysis of binocular vision, in a similar way, has been tried, but unsuccessfully. Thus far we can only say that, for each individual, personal experience has established a relation between certain complex sensations and external realities, and that not only binocular but even monocular vision is in every case the product of a judgment quickly reached, and by no means always, or even ordinarily, capable of separate analysis, because of the unconsciousness with which it is formed.

NOTES ON WATER ANALYSIS.

By Reuben Haines.

No. 1.

[Read before the Chemical Section, Franklin Institute, Sept. 5, 1882.]

Within the past few years renewed efforts have been made to place the much troubled subject of water analysis in a more satisfactory condition. Among others may be mentioned the recent investigations under the direction of the National Board of Health of this country. Difficulties of an extraordinary character are experienced, inasmuch as the chemist is called upon not only to estimate quantitatively substances of the properties and constitution of which he knows little or nothing, and of the very existence of which he may be doubtful, but also he is expected to state his opinion as to their physiological effects when taken within the human body. In the latter demand may be said to lie in the majority of cases the exclusive interest of his client. People usually do not care much about the figures in the analysis; they simply want to know authoritatively, with certainty, whether the

water is wholesome, and if not what is the cause and how it can be remedied. To answer these questions an exact quantitative analysis is considered necessary.

These difficulties are made a hundredfold greater by the fact, apparently well established, that some of these substances, whatever they may be, whether living or dead, can produce manifest effects when present in exceedingly minute quantity. Add to this the fact that owing to different methods of analysis being used and different views being held as to the significance of the several results of analysis, the most diverse opinions have occasionally been expressed in regard to the wholesomeness of the water supply of a city or town by chemists of established reputation. Unfortunately some of these opinions have been expressed with a positiveness unwarranted by the state of our knowledge.

Surely any well-directed and well-intentioned effort to relieve this important subject of some of its difficulties is commendable. Chemists are therefore to be congratulated, as being one of the steps toward this end, on the greater disposition to recognize the respective merits and demerits of rival methods of research. The feeling is becoming more evident that no single method of analysis now used can with any probability tell the whole story, and also that chemical must of necessity be coupled with microscopical and biological studies in many sanitary water analyses. In other words, every ray of light gathered from all the various sources that can be thought likely to illuminate this confessedly obscure subject should be utilized in every important investigation. It is a matter of importance, therefore, that any method of analysis which is widely adopted should be worked in such a manner that it will give uniform and strictly comparable results in the hands of different but equally conscientious chemists. Any effort to elucidate causes of variation should therefore be welcomed, however trivial and unimportant they might at first appear. This must, therefore, be my apology in offering the present paper.

Wanklyn's ammonia method is very extensively used, but the descriptions of it and of the judgment to be placed on a given water, which are to be found in the five successive editions of his manual of water analysis, are, on a number of points, in the opinion of some, by no means entirely satisfactory. Neither do the various scattered papers on this subject by other chemists agree very well among themselves or with Mr. Wanklyn's instructions. It thus appears evident

that Mr. Wanklyn unfortunately has not described his method with sufficient detail on some important points so as to enable other chemists less experienced in water analyses to obtain strictly reliable results, or as nearly so as is attainable by his method. In its conception the method appears very simple and easy to follow, but the precautions found necessary by experience are numerous, and on these points Mr. Wanklyn allows his readers to rest too much on their own unaided judgment, or states his opinion in a brief, *ex-cathedra* manner not at all satisfactory to the thoughtful student when he finds an opposite opinion expressed by an equally accomplished chemist. This is particularly to be regretted where, unlike the analysis of a mineral ore or technical product, the judgment of the chemist based upon the analysis is of far greater importance than the analytical results themselves. In such cases the fullest explanations of the basis of the opinions expressed should be given by the author of the manual, especially in the later editions when the method is being extensively adopted. It is, therefore, a matter of regret that the last edition contains so little change from those preceding by way of suggestion, hint, or explanation which ought reasonably to follow from more extensive use. It seems probable that to this deficiency may be traced many erroneous, and in some cases worthless, analyses that have been made, upon the results of which the question of sanitary improvements on a large scale were to be decided.

In view of all the points just considered, I offer the following description of the manner of working the method, not imagining, however, that it is the best that can be devised, but simply as one which I have found to give satisfactory results. I hope it may prove suggestive of improvements and may lead to a uniformity of practice. As compared with this the mere statement of results in a uniform manner is of comparatively insignificant importance, although also desirable.

For the details of the method, which are not included in this paper, I refer to Wanklyn's Manual.

On the Albuminoid Ammonia Method.

In working the ammonia process of Wanklyn it is advantageous to connect the retort and condenser by means of a short piece of wide rubber tubing. The retort, selected of commercial pint size, but capable of holding more than one litre, should have a rather narrow neck,

which can easily be thrust within the tube of the Liebig condenser to the distance of five or six inches without the glass surfaces being in actual contact. If the retort neck is rather too slender slip a second short piece of rubber tubing up the neck and thrust the latter into the condenser until the two pieces of rubber overlap each other. The rubber should always be tied down with cord, both on the condenser and on the retort, because it expands and loosens its grip on the glass during the distillation. Before connecting them, every part, including the rubber, is thoroughly washed with clean tap-water and they are then immediately put together.* The retort, if it is new, or if it has been used just previously for very bad waters, should in the first place be rinsed out with about 10 cc. of concentrated sulphuric or hydrochloric acid. When the apparatus is once set up many analyses may often be made on successive days, or at longer intervals, without its becoming necessary to disconnect the parts. In this case, before pouring in the sample to be analyzed, flush the whole apparatus with tap-water conveyed by rubber tubing to the tubulure of the retort, into which a short glass tube, bent at a sharp angle, is inserted so that the jet of water is thrown directly into the neck of the retort. Into the beak, or smaller end, of the condenser a clean cork is inserted and the whole tube and retort neck filled with water. When the water begins to overflow into the body of the retort the cork plug is removed and the whole mass of water allowed to rush out. This flushing is repeated two or three times, and the outside of the beak of the condenser is also washed by pouring clean water over it. The water which has collected in the retort is removed by a glass syphon, which has been just previously well washed. At the conclusion of an analysis the permanganate liquid is removed by the syphon, introducing clean water and syphoning it out until no longer colored.†

* It may be proper to state that at the time of presenting this paper I had not read the articles on this subject which appeared during the early part of this year in the *Analyst*, in which a similar arrangement of the retort is recommended.

† It should be stated that the working details to be described may perhaps prove to be better adapted to the analysis of soft waters, or those waters the hardness of which is due to sulphates rather than carbonates. A number of the hard waters from the neighborhood of Philadelphia, which I have analyzed, are of this character. It is not likely, however, that calcium and magnesium carbonates would form any strongly adherent deposit on the bottom of the retort in a boiling liquid of comparatively high specific gravity, such as the permanganate liquid becomes. I have usually found that the deposited carbonates could be almost completely syphoned out by doing it while the liquid is still hot.

In the case of very bad waters, however, a deposit of manganese oxide often forms on the bottom of the retort, which, if allowed to accumulate, may cause violent bumping, thereby endangering the retort and contaminating the distillates with permanganate. In such cases it is necessary to disconnect the apparatus and clean out the retort with a little hydrochloric acid, taking care to wash very thoroughly afterward. The slight film of manganese oxide frequently forming high up on the sides of the retort may, however, be neglected as having no injurious influence. The prevention of this sudden bumping is sometimes a very troublesome matter. I find that it ocsasionally occurs with soft spring waters of first-class purity, and it cannot then be attributed to an accumulated deposit on the retort. A very pure spring water, which I have examined a number of times, has invariably bumped, often two or three times during a single distillation, with permanganate and so badly as to foam up and flood the condenser without any warning or noise, even when the retort neck was inclined upward. It appeared rather to be owing to a sudden liberation of steam throughout the whole mass of liquid at once, but ignited fragments of pumice introduced into the retort did not check it. On the other hand, when an organic liquid, such as diluted milk, was introduced into the retort with this same spring water and permanganate, as in Wanklyn's method for estimating the albuminates in milk, the distillation, which before was very turbulent, now immediately became regular and tranquil, with no bumping, and small bubbles breaking on the surface instead of the large ones of the previous distillation to purify the water. On syphoning out the liquid after the operation was finished a considerable deposit of oxide, formed by the reduction of the permanganate, was found adhering to the bottom of the retort.

Several methods of avoiding this difficulty have been suggested in Wanklyn's Manual and in various papers in chemical journals. Some advise introducing into the retort recently ignited pieces of pumice or tobacco pipe, or else a judicious shaking or tapping of the retort during the distillation so as to produce a wavy motion in the liquid, or inclining the retort upward so that the liquid may not enter the condenser. I have tried all of these methods, but find the following plan decidedly preferable to any of them. I watch the retort very closely during the whole distillation when the trouble is likely to occur, and at the instant that the liquid is observed to foam up snatch

away the Bunsen burner from below the retort, replacing it when the foam subsides. This may have to be repeated several times. In very troublesome cases it is well to keep the hand upon the burner ready to remove it instantly. Toward the latter end of the distillation spirting of the concentrating liquid is apt to occur. This may be checked by regulating the flame by a screw spring compressor on the rubber gas tubing and distilling more slowly. If a fourth or fifth portion of 50 cc. has to be distilled over, the flame should be lowered to prevent the fracture of the retort, or else from 100 to 200 cc. of perfectly pure distilled water should be added to the retort. The distillation should be continued until 50 cc. of the distillate developes no color with Nessler test on standing several minutes, or a least contains not more than ·005 mgm. NH_3. This can be ascertained by nesslerizing the third or fourth 50 cc. distillate while the following one is distilling. It is sometimes necessary to estimate the ammonia in the fifth or even in the sixth 50 cc. portion, but usually the fourth portion contains less than ·005 mgm. NH_3. Of course, the free ammonia must be known to be completely expelled before commencing the distillation with permanganate; hence, in highly ammoniacal waters it is best, after distilling off 200 cc., to distill and nesslerize a succeeding 50 cc. before adding the permanganate to the retort.

In many cases the precautions above given against bumping will be found quite unnecessary, and other parts of the analysis, viz., the nesslerizing the free ammonia and the estimation of the chlorine, may be attended to during the progress of the distillation. If the albuminoid ammonia distillates are nesslerized in the reverse order, the third before the second and the second before the first, a tolerably accurate guess can be made at once as to the amounts of ammonia in each. In very many cases in my experience the first portion contains about twice the second and the second twice the third. We thus know at once whether it will be best to dilute the first distillate before adding the Nessler solution. Some waters, as for example those which are turbid with organic matter, or peaty waters, will not be likely to follow this rule, and some analysts have claimed that the manner in which the distillation progresses is a means of distinguishing vegetable from animal organic manner, or at least affords information which is an aid in forming a judgment of the quality of the water. It would seem best, therefore, to measure accurately each separate distillate and keep

on permanent record the amount of ammonia which it contains.* If the water contains so much free ammonia as to give a decided color with the Nessler test in 50 cc. of the sample without distillation the free ammonia can be more accurately estimated by distilling off 200 cc. in one portion, diluting with ammonia—free distilled water, taking out an aliquot part, and diluting again, if necessary, to 50 cc.; nesslerize this and multiply by the proper factor. Some of these ammoniacal waters appear to yield four-fifths, or even five-sixths, of the total amount of the free ammonia in the first 50 cc. distilling over, instead of three-fourths, which is usually the case as stated by Wanklyn. This variation is of no practical importance, however, since such a water would certainly be condemned by either method of calculation if it comes from a shallow well or spring.

In the distillation it is necessary to have a current of water through the condenser sufficiently rapid to avoid perceptible heating of the latter, except at the outlet. I prefer to use a 4-jet Bunsen burner, and operate on a half litre of the sample. I have obtained identical results when using quantities of half litre and full litre of the same water on the same day, or as nearly identical as is possible in these colorimetric estimations. My own limit of accuracy in colorimetric observation in matching the colors I have found to be ·002 milligram of ammonia in amounts of more than ·010 mgm. in 50 cc. of water. Hence, a plus or minus error of this amount is liable to occur in every nesslerizing. I believe, however, that these errors, to some extent at least, neutralize each other, since several duplicate analyses can be made agreeing much more closely than would be the case if the errors were all in one direction. Moreover, the corresponding distillates in different duplicate analyses are often found to contain identical amounts of ammonia, which, of course, fortifies their accuracy, provided that the distillates are of equal volume. Although working on amounts of a full litre avoids the doubling of this error, there are counterbalancing disadvantages attending it. It is, of course, very necessary for the chemist to ascertain if he is afflicted in any degree with color blindness. If he is color blind only to a very insignificant extent, it may possibly be expressed quantitatively, and allowed for as a sort of "personal equation." But if this defect is very marked it is hardly necessary to say

* The author of the paper in the *Analyst* cited above recommends mixing all the albuminoid distillates, measuring out an aliquot part, and making but one nesslerizing. It might be well to compare the numerical accuracy of the two methods.

he ought to relinquish the practice of this method of water analysis, and perhaps all other methods necessitating colorimetric observation. This precaution is of some importance from the fact ascertained by statistics, that about one man in twenty is more or less color-blind. Among women the percentage having this defect is much less. I find it is very difficult to estimate the color when less than ·005 mgm. of ammonia is found in 50 cc. of the distilled water; hence, amounts of less than this figure are neglected in adding up for the total amount. I do not think this error of omission can be avoided by distilling the albuminoid ammonia in one portion, returning this to the retort and redistilling in separate portions of 50 cc. each, as was suggested by Mr. Sidney Rich, for waters containing small amounts of albuminoid ammonia. Due allowance must, therefore, be made for these possible errors in the estimations of colors, when analyses of different samples of water are compared with each other, and a slight difference in results may indicate no real difference in the quality of the waters under examination.

It is highly important to have the alkaline permanganate solution perfectly free from ammonia. This degree of purity I have been unable to obtain by following any of the directions for its preparation heretofore published. Dr. Tidy, in a paper on the methods of water analysis, read before the (London) Chemical Society, Dec. 5, 1878 (*J. Chem. Soc.*, vol. 35, page 62), states that he believes "it to be practically impossible to prepare alkaline solutions of potassic permanganate absolutely free from ammonia. I have, myself," he says, "followed with the greatest precision the details given by Mr. Wanklyn for its preparation, and, moreover, have tried a large number of other means that have suggested themselves, such as fusing the potash before dissolving, and such like, without avail. Nor have I found any permanganate solution made by others which was entirely free from ammonia. Hence it has always been necessary to estimate the quantity of ammonia in the permanganate solution, and to deduct this from the total amount obtained in the actual experiment."

In the discussion of this lengthy and important paper, which was postponed to take place at a special meeting on Feb. 6, 1879, Mr. Wanklyn, toward the close, stated that "he had never had any difficulty in obtaining his alkaline permanganate free from ammonia, and he could not tell what results might be arrived at by using impure solutions of permanganate, and allowing for the impurity" (*Chemical*

News, Feb. 14, 1879). This remark was elicited by a question in regard to some extraordinary discrepancies in the analysis of certain London waters, by two chemists, both of whom used the ammonia method. Mr. Wanklyn, however, appears not to have explained how he obtained a pure solution of permanganate.

I have found it possible to prepare the permanganate solution so pure that when a litre of it is distilled *by itself in an undiluted condition* it will yield in the first 50 cc. distillate, not more than ·005 mgm. of ammonia. To obtain it in this condition, I dissolve the required amounts of caustic potash (white sticks), and of permanganate in separate portions of ordinary distilled water; then mix, and dilute further to about 1500 cc., and boil down rapidly in a capacious flask over a Bunsen burner to about 500 cc.; then dilute again to about 1200 cc. with ordinary distilled water, and boil again, as before, to about 900 cc.; when cool make up the litre mark with water which has been redistilled with alkaline permanganate till free from all traces of ammonia and organic matter. I have secured the same result by diluting in the first place to more than two litres with ordinary distilled water, and rapidly boiling down to about 900 cc., and then at once making up when cool to the litre mark in the manner described. If I used ordinary Schuylkill river water for making the solution I found it was practically impossible to get it free from ammonia, nearly equal amounts continually coming over in the protracted distillation. In laboratories where the water supply is limited the flask need not be connected with the Liebig condenser until the boiling is nearly completed. This attachment is conveniently made by means of a large glass tube, bent at a right angle, and fitted to the flask and to the condenser by two pieces of wide rubber tubing, in such manner that it is only very slightly exposed to the action of the steam. It is scarcely necessary to add that it should be very thoroughly washed just before being attached. If, on testing the distillate, more than ·005 mgm. of ammonia is found the solution in the flask must be boiled longer or distilled water added and boiled down again as before. Care should be taken not to concentrate the solution too far, as it may thus suffer decomposition, and pass over into the green manganate with evolution of oxygen. This accident occurred twice with the present writer. This fact was also noticed by Mr. Wanklyn, as stated in the *Philosophical Magazine* for Feb., 1879. He says that "at temperatures very little above 100°C. a mixture of pure K_2Mn

O_4 and KHO evolves oxygen gas." In the concentrated liquid the boiling point rises, of course, in proportion to the degree of concentration. "The gas is evolved very freely at temperatures even below 140°C., and the numerical results accord very well with the equation $2(KMnO_4) + 2(KHO) = 2(K_2MnO_4) + H_2O + O$. Hence the permanganate loses one-fifth of its active oxygen and becomes manganate of potash." I have also found that if the requisite quantities of permanganate and of caustic potash are dissolved in separate portions of water of somewhat more than one-half litre each, and a part of the permanganate is then poured into the potash solution while quite warm, the permanganate is, in a few minutes, completely reduced to the green manganate. It seems, therefore, that the mixing should always be done in the reverse manner and when the solutions are cold; that is to say, the potash solution sufficiently diluted should be gradually added to a dilute solution of permanganate.

In boiling the mixed solutions the appearance of numerous small bubbles over the surface of the concentrated liquid will be found to indicate that the solution is losing oxygen.

With the solution made in manner described I have found some shallow well waters so pure as to yield only ·026 mgm. per litre (or parts per million) total albuminoid ammonia, without correction, and including in the calculation the ·005 yielded by the last distillate which gave the slightest color by the Nessler solution. Obviously no correction was admissible in such cases.

I believe, with Mr. Wanklyn, that it is unsafe to use an impure solution of permanganate, and make a correction for that impurity. Some time ago when using a solution of much less purity than the one described, I found several instances where, in distilling off the albuminoid ammonia from spring waters of the very purest character, the total amount of this ammonia obtained was less than the amount of correction which was to have been made for the ammonia in the 50 cc. of permanganate used in the analysis. In other words, part of the ammonia had disappeared or was not developed in the diluted permanganate in the retort.

The Nessler solution I have found to be more satisfactorily prepared according to the directions of Dr. Frankland than according to those of Mr. Wanklyn. Particular care should be taken to render it sufficiently sensitive by a little additional mercuric chloride solution. In nesslerizing 50 cc. containing ·040 mgm. ammonia the full color

ought to be developed almost immediately, and no change in intensity ought to be perceptible after half a minute has elapsed. In solutions containing less ammonia the color is developed more slowly, but with even so little as ·005 mgm. the color ought to be fully developed in less than two minutes. The whole estimation should be concluded as soon as possible for several reasons, one of which is that occasionally a turbidity will occur in the nesslerized distillates in about ten or fifteen minutes, or a bright red precipitate will sometimes be found at the bottom of the glass when exposed to bright light, both of which occurrences are altogether fatal to any accuracy. The rapidity of development of the full color produced by the Nessler solution is believed to be wholly dependent upon the degree of sensitiveness imparted by additional mercuric chloride to the Nessler solution. My experience in the rate of this development differs from the author of the articles in the *Analyst* cited near the beginning of this paper, and leads me to suppose that his solution was not made as sensitive as may be possible.

The storage bottles of the Nessler solution should be kept as full as possible, the stoppers of which may be coated with paraffin, and a smaller bottle should be kept for immediate use. For this purpose I prefer to use a 2 oz. wide-mouthed, glass-stoppered bottle, the stopper of which has never become tight, although it is not paraffined, which is, I think, an advantage in a bottle which is so constantly opened. This stopper is always replaced immediately after taking out the 2 cc. by the pipette for each nesslerizing, as the solution should be exposed as little as possible to the atmosphere of the laboratory. By using the volume pipette with proper care the flocculent sediment which gradually forms at the bottom of the bottle produces little or no inconvenience to the operator, and only a very little of the solution need be thrown away at the last. The pipette for the Nessler solution serves also as a stirrer, and should always be washed immediately before and after each nesslerizing. This can be conveniently done by plunging the stirrer each time into a larger and firmly standing cylinder containg water which is fairly free from ammonia. If river water does not give the faintest color with the Nessler test when not distilled it is sufficiently pure for this purpose. This water must of course be changed after a few testings. To make sure that everything is going on right it is well to have a blank nesslerizing cylinder handy containing water free from ammonia. By experience one can guess

quite closely at the amount of ammonia present immediately after dropping in the Nessler solution, and it is not necessary to wait for the full development of the color before making up the comparison cylinder. Hence, all the distillates and comparison cylinders can be nesslerized in rapid succession. Since it is only occasionally that the experienced analyst finds it necessary to make up anew a second comparison cylinder of a different strength, the whole series of Nessler tests can often be completed within a very few minutes if all the apparatus required is ready for use at his elbow.

I have dwelt particularly on this point because some chemists appear to have been dissatisfied with the slowness and tediousness they have experienced in this operation, and on this account have been led to devise various methods and appliances for shortening it. Thus, some have used comparison tubes containing standard caramel solutions, either simple or those brought to the proper tint by the addition of colors like aniline red, etc. Otto Helmer devised a cylinder, graduated on the side and with a glass tap at the base, and estimated the amount of ammonia by the height of the column of liquid when the tints were equalized. Prof. A. R. Leeds has devised an expensive apparatus carrying two glass reflectors, between which the nesslerized cylinders are placed, and the colors estimated in comparison with light passing through a prism containing a solution of caramel and aniline red. Although I have never used Leeds' apparatus, I think I can endorse the opinion I have seen somewhere expressed by an English chemist that all of these supposed aids will prove only to be hindrances to the experienced worker, and their proper management consumes more time than the original unaided method. It has some years ago also been shown that it is frequently impossible to secure the proper tint by caramel solution, and a mixture of caramel with such colors as aniline will be apt to change in a short time on exposure to light. I have tried the simple caramel solution, and, as it has been the experience of other chemists, I have been compelled to abandon it. I have no doubt, however, that for such colorimetric estimations as Eggert's method for carbon in steel Leeds' apparatus will prove a useful aid.

In regard to the time consumed in nesslerizing it will be understood that the purer the water under examination the more rapid are the testings; for with impure waters the distillates must be measured, diluted and an aliquot part taken for the nesslerizing which latter may

have to be repeated several times before a convenient color is produced. It is best not to have the color too deep, nor should it be very faint. It is best not to attempt to estimate accurately colors deeper than that produced by ·06 mgm. of ammonia in ·50 cc. of water.

Notwithstanding Mr. Wanklyn's assertion to the contrary, I believe perceptible ammonical vapors in the laboratory are decidedly objectionable, and therefore other analyses involving the use or evolution of ammonia or ammonical salts should not be permitted in the same room at the time the water analysis is made.

It is stated that the standard solution of ammonium chloride should never be run into the comparison cylinder *after* the Nessler test has been added because a turbidity is thereby produced which spoils the color estimation. While this is generally true for the addition of more than 1 cc. of Wanklyn's ammonic chloride solution I find that if the comparison test already made is not strong enough it may often be enforced by a few tenths of 1 cc. of the NH_4Cl solution without producing any turbidity at all. Care should be taken, however, to stir very thoroughly with the pipette or the color may not increase perceptibly. Sometimes a peculiar turbidity will occur, however, on the slightest after-addition of NH_4Cl. Conversely, when the comparison test has been made a little too strong, a few tenths of 1 cc. of NH_4Cl solution may be added to the cylinder containing the distillate, so as to make the colors exactly similar, and the amount of this addition is deducted from the amount of NH_3 found in the comparison tube. Greater care must be taken in this case, however, to avoid producing a turbidity since the distillate cannot be replaced without repeating the whole analysis. This method of working economizes both time and the amount of Nessler solution used in each analysis.

For the process of nesslerizing I find it convenient to use cylinders made by being blown from perfectly colorless test-tube glass, free from lead, care being taken that all the set of tubes are of the same diameter (or rather capacity) and that they have good flat or slightly depressed bottoms so as to stand well unsupported. I prefer them to be of such size that 50 cc. of liquid make a column about five inches in height, the tube itself being 15 centimetres in height and 22 or 23 milimetres in diameter. Three dozen of these cost me at the rate of seven cents a piece, and they are all very nearly of the same capacity with only two or three exceptions. A moulded base is very unsatisfactory.

The color is best determined by looking perpendicularly down through the cylinder placed on a white porcelain tile, checking by raising the cylinder vertically an inch or two and observing again, or placing a smaller piece of tile at an angle of 45° beneath it, and also by holding the two cylinders side by side, flat against a white tile held vertically and opposite to the light. The nesslerizing should be done close to a window for which perhaps a northern exposure is best, although this may not be important. I do not at all like Dr. Frankland's method of observing the color of the miniscus by viewing it from above at an angle of 60°. Perhaps I should call this Prof. Miller's method, it being first suggested, I think, by him.

In point of economy of time, a burette holding 15 or 20 cc. is preferable to a pipette for the delivery of the NH_4Cl solution. It may be of the ordinary Mohr pattern, a glass stopcock being both unnecessary and troublesome.

In several cases in my experience the distillates containing the free ammonia had a peculiar odor. In one instance where the free ammonia was very large the distillate possessed what may be described as an "earthy" odor. In this case the albuminoid ammonia was remarkably small in amount. Tidy's permanganate method also showed an extremely small amount of oxidizable organic matter. To this case I shall have occasion to refer at a future time.

In another case of the water of a terribly polluted well, situated in the basement of a residence, on distilling with sodic carbonate a strong, disagreeable odor was noticed in the free ammonia distillate. This odor was similar to, but more intense than, the odor which the water itself possessed on being warmed. The free ammonia was 2·860 parts and the albuminoid 0·512 parts per million. The chlorine, nitrates and total solids were all very low in amount. Sewage contamination was therefore improbable. The color of dilute permanganate was, however, discharged rather rapidly. The water had an opalescent, or whitish, appearance in a flask, and there was a large amount of floating sediment of a fungoid character of very peculiar appearance as shown under the microscope. Some of these masses were groups of regularly distributed white opaque spheroids, while one resembled nothing better than a fragment of the most delicate white floss of fine filaments massed together in a dense white mass nearly as broad as long. I can find no illustration of microscopic fungi at all closely resembling these substances. The special point to be considered just

now is the odor occurring in the free ammonia distillate. It seems very probable that this was due to organic matter which volatilized unchanged on boiling with sodium carbonate, and although condensed with the free ammonia was not estimated as ammonia, and was consequently lost in the analysis. This appeared to me to be the explanation at the time of the analysis, October, 1880. It did not, however, occur to me at the time to repeat the distillation with alkaline permanganate alone for the total ammonia, as suggested by Prof. Remsen of Johns Hopkins University, and also lately by Mr. Marsh, of Princeton College, in a paper in the *American Chemical Journal*, Vol. iv, No. 3. The authors have shown that there is frequently a considerable discrepancy between the added free and albuminoid ammonia determined separately and the total ammonia developed by distilling with alkaline permanganate alone. The latter being always in excess in these cases, seems to indicate a frequently occurring loss of volatile organic matter in the ordinary distillation for the free ammonia. Hence, it would appear advisable always to repeat the distillation in this manner so as to check the results.

On July 17th of this year I collected myself a sample of water from the fore-bay of the Fairmount Water Works at a point under the stone bridge, and collected at arm's length below the surface of the water. The results of analysis were as follows:

Free ammonia, ...	½ litre used:	0·150	mgm. per	litre.
Albuminoid ammonia, . . .		0·110	"	"
		0·260	"	"
Total ammonia by permanganate,	¼ litre used:	0·264	"	"
Difference for volatile matter, ...		0·004	"	"

This difference is, however, clearly within the limits of error of nesslerizing, and can therefore be rejected, and it is safe to assume that there was no volatile organic matter present in this sample of Schuylkill river water. It would have been better to have used at least a half litre for the total ammonia, but the amount of the sample collected did not admit of it, since the rest was used for the estimation of the oxygen required to oxidize the organic matter by Wanklyn's "moist combustion" method, as described in the fifth edition of his Manual. This gave the oxygen required by moist combustion to be 3·75 mgms. per litre. This oxygen required for the Schuylkill water

has been found to vary at different times from 2·75 to 3·75 mgms. per litre.

The sample was collected about 10 o'clock A. M., a couple of hours after the fore-bay had been raked free from the grass and rubbish, as is done every morning. The water was not flowing over the dam, therefore, the analysis represents pretty fairly the average condition of the river at Fairmount on that day. A sample collected at the same time at the entrance to the fore-bay gave very nearly the same results.

At the time of this analysis the thorough dredging and cleaning out of the fore-bay of Fairmount Works, as recently determined upon by the City Councils, had not yet been commenced.

It may perhaps be shown by future investigation that the differences in the ammonia supposed to be due to volatile organic matter may more frequently occur in the analyses of well waters than of river waters.

REPORT ON EUROPEAN SEWERAGE SYSTEMS, WITH SPECIAL REFERENCE TO THE NEEDS OF THE CITY OF PHILADELPHIA.

By Rudolph Hering, C.E.

(Continued from page 303.)

V. Junctions, Connections, Overflows and Outfalls.

The remaining features of the sewers requiring consideration are their separate termini or the points of reception and discharge. Generally speaking, they should enable the sewage to enter and to discharge, so that no detention, irregular flow, eddies or backwater are caused, as all of these disturbances produce deposits which it is the first object of a perfect system to avoid.

(*a*) Junctions.—When two or more sewers join to form one, several designs can be used, according to circumstances.

As junctions presuppose a change of direction, and as this may retard the velocity, its effect must be reduced to a minimum or counterbalanced entirely. The latter can be done by decreasing the angle as much as possible and by a corresponding increase of gradient. The amount of fall available, therefore, will govern the least radius of curvature advisable. The following are the formulæ which were

generally recommended to determine the relation of the degree of curvature and the additional fall.

$$h = \frac{a.\ c.\ v^2}{579{\cdot}4} \text{ (\textit{Weisbach.})}$$

$$h = \frac{v^2 \sin^2 a \times 0{\cdot}000{,}003}{\sqrt{r}} \text{ (\textit{Robinson and Beardmore})}$$

$$c = 131 \times 1{\cdot}847 \left(\frac{r}{b}\right)^{\frac{7}{2}}$$

h = additional fall to overcome friction.
v = velocity in feet per second.
a = angle in degrees.
r = radius of sewer.
b = radius of bend.
c = coeff. depending on $\frac{r}{b}$.

Junctions of large sewers are usually covered by funnel-shaped arches. In England, Frankfort and Hamburg these are almost exclusively used. In Berlin and Paris cylindrical arches and rectangular chambers are preferred, although as a rule, they require more material and offer a much greater chance for deposits. An important feature of a sewer junction is the tongue, forming the terminus of the walls between two sewers which, gradually diminishing in section, are extended into the chamber. Its purpose is to fill by masonry or other material that portion of the space which is not necessary for the flow of sewage and which otherwise gives a cause for eddies and deposits. The design is obtained by simply extending the lower half of two adjoining sewers, until they naturally intersect. The ridge, which is thus formed, runs out to a point at the bottom and is usually capped by dressed stone, neatly rounded.* With these tongues, deposits cannot occur at a junction any more than in the sewer.

Pipe sewers which, on the Rawlinson principle, should be straight between two points of access, must make their entire turn within the man-hole, half-pipe curves often being placed in the bottom. For these short turns a extra fall is of course necessary. When pipes are joined in a man-hole it is much better to carry them through in half-pipes, without a drop or break, than to adopt the "pot and pipe" system, as in Danzig, where the man-hole acts as a basin for deposit.

* See Appendix No. 4, Pl. VI.

A word must be said regarding the relative heights of joining sewers. In order that two streams of sewage may unite and continue their course without retarding the velocity, either below or above the junction, it is necessary that the surface of the water in each should be at such relative heights that backwater is not caused in any branch. The smaller sewers, therefore, require adjustment to the larger ones. This may be done in two ways, either by so narrowing and shaping the smaller branch that the height of water from the same rain-falls would rise about to the same height as in the larger one, or by simply raising the former so much above the latter that the same result is attained. The first plan is seldom necessary, and is more expensive and difficult to construct than the other. To carry out the principle to a nicety in each case very often requires a difference of elevation which is not practicable, therefore it is best to consider not the height of the storm-water flow, but only the ordinary stage of water (existing about $\frac{9}{10}$ of the time) when the sewage alone is flowing in the sewer, and to design the junction so that it will answer this case. In other words, the branches should be at such elevations that the *ordinary* flow in the smaller sewers is at least at the same level as that of the larger ones. This precaution is frequently but not generally carried out in Europe. In Frankfort it has been most carefully considered.

In Philadelphia, sewer junctions have not been made according to any system. Three feet sewers are joined often without a substantial arch and without a tongue to prevent deposit. Often they unite at right angles or nearly, so that an obstruction and backwater must occur during heavy rains. Large sewers are joined at better curves, but also without a tongue, and their relative heights are not unusually adjusted, so that the inverts are on a level, causing backwater in the smaller one.

The direction of improvement is therefore indicated.

(*b*) Connections.—By connections I will designate the junction of the house-pipes with the common sewer.

The comparatively small amount of water they carry does not give them the same importance as the junctions of large sewers, yet the same principles govern. The water from the house should be discharged so that it will not impede the flow of the sewer, and it should itself not be subject to permanent backwater.

In the modern works in Europe great care is taken in giving the connections an angle of about forty-five degrees or less in the direction

of the flow. While sewers are being built, the connections are provided for at once in nearly all the towns, and if not immediately used, they are temporarily closed. At some places the city builds the house connection to the inside of the front wall of every house, as in Berlin; at others, to the curbstone; at still others, only through the sewer. A "Y" branch for pipe-sewers, and a slant pipe or a block of terra-cotta or of cement for brick and concrete sewers is inserted opposite each property in every case.

In Philadelphia, it has become customary, within the last few years, to place the connection-pipes into the sewers while these are being built. It has been done consistently only with the main sewers. The others generally receive them only where immediately needed, and then in rare cases they have been made properly. Formerly, when a house was connected, the sewer was broken into, a pipe often carelessly inserted and left to project into the sewer. Many breaks during storms have been traced to such imperfectly made house connections. Now, either a straight pipe is inserted at right-angles to the current or a "slant" pipe. The latter, too, is commonly placed at right-angles, making a vertical instead of a horizontal angle, which entirely defeats their real object.

To prevent a retardation of flow, the connection piece should therefore be built into the sewer firmly and accurately with no projection whatever. It should be placed at an acute angle to the flow, and to prevent back water the velocity of the entering water should, if possible, be greater than that in the larger sewer.

(*c*) OVERFLOWS.—Economy demands that rain-water after entering sewers be led into natural channels, as directly as possible, unless this is objectionable for some reasons, instead of having large underground works for the purpose. When purification is required, it is likewise necessary to relieve the sewers of the greater part of the rain-water. Overflows, therefore, must be constructed at certain points from which the water, when it becomes sufficiently diluted, can escape into a river or creek. But this can be done only where the sewers are intercepting, not, of course, where they themselves take the nearest course to a natural outfall.

As our city has no intercepting sewers where the consideration of overflows is of any moment, these remarks apply only to their future use, which, however, cannot be very distant. When it will become necessary to prevent the sewage from flowing into the Wissahickon and

Tacony creeks and into the Schuylkill and Delaware rivers along the wharves of the city, storm-water overflows will have to be built in order to decrease the size of the intercepting sewers.

They are a very common contrivance in Europe,* and generally consist of a wide shallow opening at the side of the sewer to be relieved, placed at such a height as will insure to the overflowing water the degreee of pollution permitted, and not subject the sewer itself to an unsafe internal pressure. An overflow must be wide and shallow to provide for a sufficient bulk of a thin sheet of water running over, and it is then gradually reduced to a circular or egg-shaped channel, in which the water is carried to the rivers. When the intercepting sewer runs entirely below a crossing valley-line sewer another device is generally used by which the ordinary flow of sewage drops into it through an opening, but the storm-water, having a greater velocity, leaps over and continues its course.

The location of overflows is mostly at old valley-line sewers which are utilized for the purpose, or they may be at any other convenient point.

(*d*) Outfalls.—The proper point or points of ultimate discharge of a system depend on several conditions. First, when the sewage is to be purified, the outflow must be at the locality where this is to be done, and at such an elevation as will command its distribution. Secondly, when the sewage is to be discharged into a water-course, the outfall must be situated so that the discharge will be effectual, and so that it causes the least possible nuisance.

The first case needs no consideration, as the Philadelphia sewage can be discharged into the Delaware at outgoing tide for a time longer than would demand consideration at present.

The second case is treated in Europe as follows: In London the sewage is taken ten miles below the city to the banks of the Thames. There it is stored in reservoirs during incoming tides and discharged into the river at and after high tides. In Liverpool the sewage is discharged into the Mersey from nine outfalls in front of the city, outside of the docks and above low water. The ordinary tide ranges 21 feet, and the current is swift, so that the sewage is dispersed very quickly. In Hamburg the discharge is into the Elbe, opposite the city, by means of a few main and intercepting sewers. They are extended into the current by submerged conduits on the bottom of the river.

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* See Humber on Metropolitan Drainage and Appendix No. 4, Pl. VIII and IX.

The other large cities either require purification or are in a transient condition.

In stating what outfalls are required for Philadelphia, a discrimination must be made between what is needed at present and in the future.

As I will speak of the latter further on, the first shall only be considered now.

The present outfalls into the Schuylkill and Delaware rivers are at very different elevations and positions. Some are below low-water and range to others above high-water; some are at the head of the piers and others in the docks.

When it becomes necessary to intercept the sewage the elevation of these outfalls will have an important influence on the cost of so doing, and it is well, therefore, to consider this subject in advance, so that they will suit an ultimate system. Apart from it, the following points should be held in view: In order to have a complete discharge of the sewage at certain intervals, outfalls of the valley-line sewers should terminate at an elevation which admits of the surface level of the ordinary flow of sewage being above mean low tide. In order to have the most effectual discharge of storm-water its hydraulic gradient should be regulated with regard to the highest tides.

In other words, sewers of an effective vertical diameter *less* than our tidal range (six and a quarter feet) should be adjusted from the high-water mark, sewers with a *greater* effective diameter from the mean low-water mark.

If adherence to this principle is not possible at the wharf line, it is possible and should be carried out at a short distance from it, and the outlet can then even be entirely submerged.

It may become advisable at some points to lead the sewage into the current away from the shore, and for this purpose a submerged outlet below the reach of the keel of large vessels is practicable and efficient, as in Hamburg and in a few other places, being simply of framed timber loaded and anchored to the bottom.

As heretofore, I must now refer to these structures, as applied to the *separate* system.

Junctions of sewers carrying sewage alone, require no different treatment from that indicated; the same principles apply to the sewers proper and are also suitable for the rain-water channels.

This can also be said of house connections. An acute angle is even

of greater importance in this case, because the velocity in a small sewer can be more readily affected by its retarding influence than in a large sewer.

Overflows do not occur in the separate system except at pumping stations, where they are always provided for, to operate in case of accident.

Finally, outfalls of the separate system must answer the same requirements as those of the combined. The rain-water channels, if they receive only rain-water, can of course have outfalls at any place, without causing a nuisance.

It is necessary yet to state any special features which concern the *construction* of junctions, etc.

After what has been said in the previous part, it must be added that the care which was considered necessary in the selection of material and labor for the sewer proper is even more necessary here. The strains upon the work may be greater and, therefore, require additional strength. The irregular movement of the water will require neatly finished corners, surfaces and edges to avoid eddies or retardation and deposit.

The tongues in junctions should be made of dressed stone or moulded in concrete. The house connections should be made by blocks, either of terra-cotta or moulded in cement, in preference to using "slants," because the brickwork can not be as readily fitted to a round pipe.

VI. Appendages to Sewers for Inspection, Ventilation and Flushing.

It is now in place to examine the appendages to sewers which are to facilitate their maintenance. They are the means for access, for a thorough circulation of air and for cleansing.

(*a*) For Inspection. *Manholes.*—From the uncertain and irregular nature of the substances that enter sewers it is necessary to be able to inspect or have access to them, so that the nature and place of any obstruction can be readily determined and the object removed. Manholes and lampholes or inspection shafts are built for this purpose. The latter are used only on pipe sewers, and alternate with manholes. A lamp is suspended in them, at times of examination, which can be seen from the latter and thus reveal any imperfections. They are much used in England.

In Philadelphia, manholes only are built because pipe-sewers have been seldom used. They are vertical shafts circular in section and covered with a grating, which again is covered by a sheet-iron hinged lid. During the last few years open gratings have been occasionally used to permit ventilation. Wrought-iron ladder-bars have sometimes been built into the shaft.

In Europe different designs are found in different cities In some the shaft is circular in section, in others it is square. The former is to be preferred, mainly because it is more economical. Steps are always built into it, and are generally of cast-iron, which does not rust as easily as wrought-iron. In frequented streets it is a general custom to enter the sewers from the sidewalks by means of a so-called side-entrance, in order not to disturb the travel. In others, manholes are placed directly over the sewer. In the former case, a double cover is used, consisting of a tightly fitting lid, flush with the pavement and a grating immediately below it. When examinations are made, the lid is left open and locked, while the grating prevents danger to pedestrians, and admits air and light.

When manholes are in the street they are almost always provided with means for ventilation. For this purpose the cover is often a grating. To prevent street dirt from dropping through into the sewer different provisions are made. In Berlin, a sheet-iron plate is placed a few inches below the grate, the latter having holes around the periphery, while the former has them in the centre. It is lifted out and cleaned every few days. In some towns, where the gratings are open in the centre, there are buckets suspended under them to catch the dirt and which are periodically lifted out and emptied. In England there is generally a small catch-basin to one side of the manhole, with a side opening between them. In this case the manhole has a closed cover and the catch-basin a grating.*

To determine the proper design for Philadelphia is somewhat difficult, as the conditions are very dissimilar.

In Europe, every large city has a well organized and trained body for a regular and systematic inspection, flushing and cleaning of the sewers. The latter are, therefore, seldom foul nor is the escaping air objectionable; and the catch-basins, buckets or plates, can be regularly freed from their dirt.

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* See Appendix No. 4, Plates I and IV to IX.

In Philadelphia there is no such body and the sewers are only entered, either for repairs, or when an obstruction is sufficiently great to entirely impede the passage of the sewage. The only regular cleaning done is the emptying of the inlet-basins. Entrances on side-walks would not be advisable in Philadelphia, because the obstruction in the street, when using common manholes, would not be likely to give much cause for complaint and mainly because the sidewalks are private property.

To facilitate ventilation, of which I shall presently speak more fully, a direct communication from the sewer to the street has been found to be of great importance and should be gradually introduced wherever it does not cause an absolute nuisance, in which case less effective or more costly provisions are necessary. Manholes ought, therefore, to be ventilating as much as possible, and, what concerns us at this place, should be provided more generally than heretofore, with a grating instead of a closed cover.

In order to avoid the street dirt from dropping through such gratings into the sewers, which is as important as preventing its entrance through the street inlets, the simplest and most convenient arrangement is to have a pan or bucket hinged to one side of the cover and resting with a projection on the other, with enough space around it for the air to escape. The grating then would have holes only in the centre above the pan. Whenever the streets are swept, it would be a simple matter to lift up the gate and swing the pan over, which would throw the contents on the street.

Finally, I would suggest that cast-iron steps, or foot-irons, be built into every manhole, so that a permanant and easy means of access may be had.

With these points receiving attention, I trust that our manholes would better answer their purpose. The details of construction as used in other cities will be seen from the accompanying drawings in Appendix No. 4.

The distance which manholes are apart also varies in different localities. Generally, experience has shown that for small sewers there should be two in one of our squares, or about two hundred to two hundred and fifty feet apart. For large sewers this distance can be much greater, unless they are required for ventilation.

Lamp-holes.—Where pipe-sewers are built, a manhole may be saved at certain points by inserting a vertical pipe, covered with an iron lid

or grate, and into which a lamp may be lowered from above. Care must be taken to prevent dirt from dropping into it, which is best accomplished by a small catch-basin at the top, with the pipe projecting in its centre and the gate openings around the periphery.*

(*b*) For Ventilation.—The question of ventilation is one which is of paramount importance to a sewerage system, in order to keep it in a sanitary condition, and it is one which has received much greater attention in Europe than here. In comparatively few instances we have placed open manhole covers in the streets, to allow the escape of gases, but this, although relieving the sewer of any pressure, has sometimes rather caused a nuisance, on account of strong exhalations.

A great deal of discussion has been had upon the arrangements essential to a proper ventilation, but the matter can, I think, be narrowed down to the following points.

The changing quantities of sewage and rain-water, and the difference in the temperature of the sewer-air and the atmosphere, produce corresponding changes in the quantity of air contained in the sewers, which will consequently sometimes be drawn in and sometimes expelled. Provision must be made for this pulsation, because otherwise the numerous water-traps connected with the system will be forced, in order to establish equilibrium, and the sewer air can then enter the houses.

There are three effectual ways of accomplishing the free exchange of air. Either special shafts are constructed to a height which will enable the air to disperse unnoticed, or openings to the sewer are provided in the roadway, or, thirdly, the soil-pipe of every house acts as a ventilating shaft, not only for the house system but also for the sewer. Any one, two or all of these methods are used in Europe.

Special shafts have been built in some towns, notably Brighton and in Frankfort-on-the-Main. Unless circumstances are peculiar, such shafts are not only expensive, but their effect is not in proportion to the cost over simpler contrivances. They have, therefore, not been used in new works as a rule. Street gas-posts have been suggested as ventilators, have been tried but almost entirely abandoned. Only one instance, in Glasgow, where a sewer was ventilated in this way came under my notice. Air for factory furnaces has been drawn from sewers, but this has likewise been abandoned, except in isolated cases.

Openings into the street, after trials in a great many places and during

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* See Appendix No. 4, Pl. IV.

many years, are now considered not only the most effective ventilators, but also not in any way objectionable if the sewers are kept in a proper condition, as they always should be. With hardly an exception, they are used in every drained European city, and give no cause for complaint. The inlets also, as already mentioned, are not trapped and assist ventilation in certain cities, as Paris, Hamburg, Leeds, Berlin and occasionally in London. But generally, it is preferred to limit the openings to the middle of the street, because the inlets, being at the footpath, could more readily annoy persons by any exhalations, especially when the cleaning of sewers is imperfect. Charcoal and various chemicals have sometimes been placed in manholes and other ventilating structures to purify the air by letting it pass through or over them. But these methods are rarely used any more, because the expense is generally disproportionate to the benefits derived from them.

Finally, ventilation of sewers through soil-pipes is used extensively, if not wholly, in continental towns. The odor arising from matter discharged in the house alone is generally stronger than the effluvia arising from the sewer, and if the soil pipe is secure against the former, it is certianly safe against the latter. An objection to this, although sometimes raised, can hardly be substantiated in view of the satisfactory experience in the continental towns. In order to ventilate the soil-pipes alone there must be a lower as well as a higher opening. Then, too, it seems better to have it in the sewer than at the pavement, where an occasional down current would be noticeable.

It is advisable, however, to have both street openings and soil-pipe ventilation. By this means the air may either be drawn into the former and up the soil-pipes, when, as is mostly the case, the temperature in the latter is higher, or it may be expelled from both during a sudden fall of rain, and again drawn in when the water lowers. In the latter cases, the street openings would act almost alone because of a more direct communication with the air and in giving less frictional resistance to it, but otherwise and especially in small sewers, and during the winter when snow is on the ground, the draught up the soil-pipes would be of much benefit to the system.

I believe, from the impressions gained, that this method of using both soil-pipes and open street gratings, carefully designed, is destined to become the most acceptable one for sewer ventilation, because it gives free circulation at all times with the least objectionable features. Yet

it could not be recommended for our city without certain concurrent changes.

The stench arising from our sewers is unusually strong. It is not only caused by their average foul condition but very often by the filtration into the sewer of illuminating gas from leaky pipes. That the latter circumstance is exceedingly common is attested by an examination of the odor arising at summits, and by one or two explosions every year, which upon investigation, have heretofore always turned out to be caused by leaks in the gas mains. With filth lodging in the sewers as a permanent producer of foul odors, and the frequent leaks of illuminating gas, ventilation into the street would be a nuisance at many if not at all points. But with these two points removed, the odor in sewers is not disagreeably strong. It is not noticeable at the surface, except within a few feet of the point where it escapes, and where it is even slight and in no way objectionable.

This condition is the common one in the best drained cities of Europe, from the impressions I received in walking through many miles of new and old, large and small sewers.

The lodging of filth and the leakage of gas into sewers can be avoided: first, by adopting a rational section, size and grade, which will reduce deposits to a minimum; secondly, by not laying gas pipes through or too near the sewers, which generally strains the joints, or breaks them; and thirdly, by a periodical inspection to discover irregularities before they become formidable and when they can be readily corrected.

Such demands are simple, reasonable, and cause no greater expense than is willingly granted in Europe, where a long experience has established their importance and ultimate economy, not only for the purpose of facilitating ventilation, but for the general sanitary condition of the works. And in so far as they could be satisfied also in our city, the conditions of the sewers would become improved, and their ventilation made easy, thorough and inexpensive; any other method, as far as I could learn, would be less perfect and and more expensive.

It is therefore to be recommended that man-holes and lamp-holes be covered with a perforated grating as soon as and wherever the condition of the sewers will permit of it. They should always be placed as far from the sidewalk or crossing as convenient. It is further to be recommended that soil-pipes, as soon as their perfect construction can be guaranteed, should act as ventilators not only for house-pipes, but

also for the sewers. For this purpose they should have as direct a course as possible, and terminate above the roof with full size, and be trapped against every branch pipe in the house, but not against the sewer.

Before leaving the subject, I am obliged to call attention, at this place, to a cause which can seriously affect the condition of sewers. As decomposition is furthered by moisture and warmth, it is evident that whatever will increase these conditions beyond an unavoidable point, increases decomposition and the foulness of the sewer. Exhaust steam, for instance, when discharged into it, does this in so great a degree that the effect can readily be noticed in all localities where this is permitted. I found quite frequently ordinances prohibiting the discharge of steam and requiring condensation, and some American cities have, I believe, similar legislation already.

As this custom naturally would have the same effects here its further extension should be deprecated as much as possible.

(*c*) For Flushing.—Under this head it necessary to speak of contrivances that we do not yet possess. A few words must, therefore, be said on the importance of flushing sewers.

A deposit of solids can never be entirely prevented in a sewer, no matter how good its shape and grade may be, because of the very nature of sewage. Therefore, an occasional examination and the removal of retained and obstructing matter is necessary. Flushing is a means by which nearly all ordinary deposit can be removed at a small expense comparatively, and which is employed in all of the well drained cities of Europe, with one exception, viz., Vienna, where, however, arrangements are being made for the early introduction of the same. A sewer is flushed by sending a sudden gush of a mass of water through it at a quick velocity, which stirs up the sediment, suspends it in the water and carries it along. To obtain this mass of water is in no case difficult, for the sewage itself will answer the purpose. Nothing has been found more effective and more economical than such a regular flushing of a sewer. Its importance is therefore apparent, and its introduction in Philadelphia would be of great value towards raising the sanitary standard of our sewerage. Practical obstacles, however, would not permit this at once, as our sewers are not designed with reference to flushing.

The circular form, where the ordinary sewage spreads only over a small segment, requires a much greater amount of flushing water than

where it is confined to a semicircle, as in an eggshaped sewer. The three feet circular section ordinarily would require the same amount of water for flushing, if it drains two houses or many hundred, because it must be filled to a certain height to have any effect, and because a three feet sewer draining but a few houses is much more liable to accumulate deposit, than one having a large stream of sewage constantly flowing through it.

It is, therefore, evident that for flushing purposes also, the size and shape of most of our sewers is not the best. Yet notwithstanding, as there is no other method known of cleaning sewers, which could take its place under our present conditions and which would be as simple, effective and economical, attention should be given to its early introduction.

The appliances used in Europe are briefly stated as follows: small pipe sewers up to nine inches in diameter are flushed, as in Liverpool for instance, by attaching a hose to a fire-plug and running a stream into a shaft at their upper end; or, the chamber often built at the head of a sewer is filled with water from a plug or tank, after its outlet is closed with a hanging flap-valve, which when subsequently raised allows the water to rush out through the pipe.

Manholes on the line of pipe-sewers can be similarly used by having flaps for each pipe. After the shaft is filled with water, then, by raising the flap from the sewer to be flushed, the entire contents are sent through it. For brick sewers, gates of iron or wood are often used. They swing on a vertical axis at the side, and close across the sewer, enabling the sewage to accumulate behind them, and to be suddenly released. Penstocks, moving vertically by means of an endless screw worked from above the sewer, are likewise common contrivances for the larger sewers.

These appliances are neither costly nor difficult to manage. Their location and distance apart depends on numerous conditions. As a rule, they are placed just above a point where the most sediment occurs, and not closer together than necessary to get the full effect of the flush, which depends on the grade and the size of the sewer, and needs a special examination in each case.

Flush-tanks, the best being those of Mr. Rogers Field, are also good contrivances for flushing, but they are confined to the use of clean water and to small pipe sewers, therefore are adapted only to the highest parts of a sewer.

In conclusion, I cannot too earnestly recommend from the good effects observed from it in Europe, that flushing should be gradually introduced in our city, wherever practicable, to free the sewers of their deposit before it accumulates to an extent which causes them to get foul

The appendages to the sewers, as thus examined, do not require much modification, if used for the *separate* system. Manholes and lampholes are equally important, if not more so, because the sewers cannot be walked through. The size, shape and position need not be different from those for the combined system.

Ventilation is also had in the same manner. Both sewage and rain-water systems, however, require it; but the latter does not need as frequent openings, because the air cannot get so obnoxious.

Also with regard to flushing, nothing further need be said, except that it becomes more necessary and important as the pipes decrease in size.

VII. General Alignment of System.

I have now followed the subject to a point where it becomes necessary to inquire into the future development of the city and its demands.

To examine into the general alignment and probable extent of our sewerage we must know in what directions the city is growing, as this can materially affect present works. It is also necessary to know the probable character of the outlying districts, in order to decide where the separate or the combined system is most suitable.

To determine upon these questions in detail will require a close and careful study. Only some general points can be given at present, and the direction indicated in which furthur inquiry is necessary.

I shall first allude to the systems of alignment as employed in Europe and then endeavor to adapt some of the results to our own city.

The growth of the cities, the topography of their sites, as well as the existing sewerage works at the time of the construction of a complete system, have all influenced the designs. A great diversity is therefore natural.

London has a complete system of valley line sewers, which follow closely the natural flow lines of water from the surface. In addition, it has the Main Drainage Works, a system of intercepting sewers, which prevents the sewage from entering the Thames, and takes it to a point ten miles below the city and there discharges it into the river at outgoing tides. A portion of the sewage thus intercepted flows off entirely by gravity. The greater part requires to be pumped; a small

portion is even lifted twice before it reaches the outfall. Although the main drainage sewers are capable of taking some rain-water,* most of it reaches the river directly through the valley line sewers into which the intercepting sewers discharge their surplus during storms.

The general alignment in Paris is partially an intercepting and partially a valley line system, owing to the topography. The sewage is discharged into the river below the city. The irrigation fields, now in preparation, receive about one-fifth of the whole amount. A small portion reaches them by gravity, the rest is lifted nearly thirty feet. The sewage from the higher grounds is intercepted so that it will not flood the lower ones during heavy storms. The sewers along the banks of the Seine are also intercepting.

Berlin has a peculiar system, due to its flat position and the necessity for purifying the entire sewage. The latter is to be collected at twelve different points, to which the sewers converge radially and from each of which it will be pumped directly to the farms.

Vienna has a natural valley line system, except two intercepting sewers, along the banks of the Wien Creek flowing through the city.

In Liverpool, the sewers partly follow the natural slopes, and partly cross them where it is necessary to intercept the storm-water. The sewers finally discharge directly into the Mersey, in front of the city.

In Hamburg, intercepting sewers predominate on account of the necessity of keeping the sewage out of the numerous canals and the Alster lakes. The sewers discharge finally into the Elbe, in front of the city.

In Frankfort, the low grounds near the river made an intercepting system preferable, and it has been carried out in a consistent manner over the whole city. Rain-water overflows, however, lead to the river directly from many points. The intercepting sewers discharge below the city.

From a study of the alignments in these cities† it will be noticed that the system of interception is made use of, partially to prevent an undue accumulation of rain-water at the foot of slopes, partially to prevent sewage or rain-water from flooding low districts, and partially to prevent sewage from flowing into the rivers in front of the cities.

A more detailed study will further reveal that an early concentration of sewage into a few larger sewers is preferable to keeping it more

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*An amount equivalent to a fall of one-quarter of an inch in twenty-four hours.

† See Appendix No. 5.

uniformly distributed over the area in a number of smaller ones, and a calculation will show the economy of this.

Finally, it will be clear that the manner of disposal of the sewage depends on the body of water flowing by or near the city. The Thames is capable of receiving the London sewage without injurious effects. The Seine, being much smaller and very far from the sea, is objectionably polluted, and the sewage is therefore to be purified on the sandy plains of Gennevilliers below the city.

Vienna discharges its sewage at present into the Danube canal, but is preparing to lead it into the Danube itself, the capacity of which is sufficiently large to prevent any pollution.

Berlin has but a small river flowing by it, which makes purification of all the sewage a necessity.

Hamburg and Liverpool are situated along large bodies of water and discharge into them without objection.

Frankfort discharges into the Main, but steps are now being taken to purify the sewage, as the danger of pollution by the rapidly growing city is fast approaching.

In Philadelphia, we have two rivers into which the sewage is discharged. The Schuylkill river is small and its dry weather flow can be easily polluted. And it forms, also, a tidal basin opposite the heart of the city, headed by the Fairmount dam, which causes sewage to deposit its heavier matter more readily than in a running stream. The Schuylkill, therefore, should not finally be a recipient of the city's sewage. A certain quantity, of course, is admissible, and this should be determined at an early day. The magnitude of the Delaware river, however, is such that we need not fear any effects of its serious pollution within a space of time which it is reasonable for us to consider at present.

It may be well to re-state at this place that the utilization of sewage, which has now been experimented upon both in England and on the continent for a long number of years, is invariably connected with additional expense to the community instead of profit, except under peculiar circumstances, such as Philadelphia does not furnish. Yet where it is necessary, for sanitary or other reasons, to prevent the pollution of streams or other bodies of water, the cost of purifying sewage is justified. As in Philadelphia this necessity does not arise, purification of sewage will not be required, and our general alignment need not be made with reference to it.

The discharge of sewage into the Delaware must, however, be subject to the precaution that it shall not cause a deposit of filth and silt along our wharves. This can be effected either by taking it out into the channel by means of submerged sewers, as in Hamburg, or by storing it during the incoming tide and discharging it after high water, as in London. The first will probably do for a long time, the latter will ultimately have to be resorted to. To determine a proper location for an ultimate outfall requires a careful study. A few conditions can here be stated. First, the point must be below the city, so that the sewage is prevented from polluting the shore lines. Secondly, as much sewage as possible must be taken to the outfall by gravity and not require pumping.

With these two points considered, representing the sanitary and economical side of the question, we can readily determine some several features of a future system of sewage collectors by examining the topography of the city.

Some time ago, I sketched out a general alignment,* having these same points in view. As I cannot at this time, in comparing it with the alignment in the above cities, see any reasons for deviating from the general plan there set forth, at least as far as the near future is concerned, I shall consider it as embodying what I would now recommend and therefore not enter into the details at this place.

Two intercepting sewers, I concluded, will become necessary at an early day: One, the Manayunk sewer, to keep sewage from entering the Fairmount pool and polluting our drinking water, another from polluting the docks along the Delaware. The remaining sewers would not be needed for some time, but their best location and grade should be determined in order to bring the valley line sewers crossing them hereafter to a proper and suitable gradient.

I must now add two more intercepting sewers, also deserving of consideration at an early day, namely: First, the intercepting sewer, which is to prevent the sewage of the north-eastern part of Germantown (Wingohocking creek) from polluting the Frankford creek, which may temporarily be discharged into the Hart creek sewer. Secondly, the sewer which skirts the south-western part of Germantown and which can temporarily discharge into the West Cohocksink sewer, or, if it is already built, into the Manayunk sewer at the Falls. By it the remain-

* Proc. Engineers' Club, Vol. II, No. 1.

ing part of the Germantown sewage can be intercepted and prevented from flowing into the Park, the Wissahickon creek and the Schuylkill river above the dam.

Germantown and Chestnut Hill are, I think, without having made as close an examination as it will require, well adapted for the application of the separate system; and an early study of the matter is advisable in order to regulate the construction of sewers already going on in the district. With the separate system applied in that locality, the rain-water can flow, as at present, into the Wissahickon, but the sewage alone could be carried in a small sewer, less than 4 ft. diam., across the water-shed and discharge into the West Cohocksink.

Regarding the general alignment nothing further need be said. But the detailed alignment requires a few more words.

As a rule, the sewers in Philadelphia are laid in the centre or on one side of a street. The house branches in broad streets are therefore rather long, or if on one side, unevenly long for the properties on the two sides. To avoid this, it is customary in nearly all European cities to build a sewer on each side of the street, under the gutters or the sidewalks, whenever its width exceeds a certain measure, usually 60 to 70 feet. We have few streets exceeding this width, but it would be well in these few to lay two sewers, not only for the reasons just mentioned, but to avoid the frequent breaking up of the pavements, which are generally of a better class in wide streets and are seldom perfectly replaced after house connections are made, and because it is often more economical for the property owners.

Another point deserving consideration is the avoidance of a sudden decrease of the gradient, by which not only deposits occur, owing to the decreased velocity, but in many cases a flooding, as the hydraulic gradient during heavy rains is likely at such points to rise far above the sewer. In London and other places this effect has clearly been shown. To avoid it the alignment should be made so as to have an intercepting sewer near the foot of a slope, as can clearly be seen in the maps of Paris and Liverpool,* and to gradually decrease its grade.

Alignments should further be made so that a free discharge is possible during high water. Partial interception is resorted to for this purpose, in the case of low-lying valleys, as in London, Paris, Hamburg and other places. In our city, the Cohocksink valley offers this

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* See Appendix No. 5.

feature. Instead of permitting the sewage of high parts of this area to flow into the valley with a comparatively heavy grade, and then to continue its course with a very light grade, which may at times of high water entirely vanish, it is both more efficient and economical to intercept as much sewage and rain-water as possible, in order to discharge it freely at high water, and to confine the low valley line sewer to the comparatively small area, which cannot be intercepted. Examples of this method of treatment are found in nearly every city I visited.

Finally, it is necessary to state that the alignment of the main sewers becomes most important when a city has reached dimensions like those of Philadelphia. The continual extensions of sewers in every district make it a matter of great economy to determine early upon an ultimate and uniform system, to which all present works will in future be subservient. Every large European city has its general system fully worked out, as have also several American cities, and the question is no less important for us.

It will not be necessary to enter into the minute details as yet, but simply to establish the alignment, depth, grade and size of the principal intercepting sewers required in the future, so that, when additions to or alterations of the present works are made, it is all done to suit an ultimate system.

Because the question is one of many difficulties for this city, on account of the large extent and varying characteristics of the drainage areas, an early study is only the more imperative.

Herewith I conclude my remarks with reference to the various parts of sewerage systems in general and detail, having a bearing upon our own needs. It will now be necessary to devote some remarks to the management and cost of works.

(To be continued.)

The Telephone in the Fifteenth Century.—Leonardo da Vinci makes the following statement: When one is upon a lake, if he puts the opening of a trumpet into the water and holds the point of the tube to his ear he can perceive whether ships are moving at a remote distance. The same thing occurs if he thrusts the tube into the ground. Then also he will hear what is going on at a distauce.—*Beiblätter*, vi, 190. C.

EXAMINATION OF WATER AND AIR FOR SANITARY PURPOSES, WITH REMARKS ON DISINFECTION.

By Romyn Hitchcock.

[A paper read before the American Association for the Advancement of Science. Montreal, August, 1882.]

It is not my purpose in this note to bring before you any new discovery or observation, but rather to call forth an expression of the opinion of chemists who have been engaged in examinations for sanitary purposes. The question I propound for discussion is this:

Under what circumstances can a chemist condemn a water for household use?

It is well known that the presence of chlorides, nitrites, etc., in water, is indicative of contamination with sewage, or with organic matter of some kind, and, by general consent, such waters are regarded as unsafe for household use. On the other hand, it must be admitted that the constant use of such waters for drinking is only occasionally followed by diseases which can be attributed to them. Certainly chlorides and nitrites are incapable of producing contagious diseases. Therefore, there must be another element in those waters which produce typhoid fever for example, that may or may not accompany the compounds mentioned. At present it is almost universally conceded that this element is a living microscopic germ, which develops and multiplies in the water. If this is true, it is obvious that the results of a chemical analysis are quite incompetent to prove the healthfulness of a water.

Granting this, it may be argued that chemical examinations are quite useless for sanitary purposes. The fact is quite otherwise. For although the chemist cannot detect the germs of disease, which likewise baffle the scrutiny of the microscopist, his analysis indicates the sources of contamination. It enables us, therefore, to trace the contamination to its source and thus determine its nature.

Perhaps it will be a somewhat startling assertion to say that the drainage from vaults containing human dejecta is not necessarily unhealthful. Yet the truth of it is demonstrated by the immunity from contagious diseases of thousands of families whose wells are situated close by and below such vaults. Sanitarians become greatly

excited over the condition of affairs in this respect all over the country, and they predict most direful epidemics. But, somehow, the epidemics do not come. Chemists examine the water, Boards of Health order the wells closed, and families complain of the injustice of it because they have never suffered from the use of the water. Evidently, theory and experience do not correspond.

Nevertheless, the explanation is simple enough. Let there be a single case of typhoid fever in a house when the well is thus contaminated, and the probability is that those who drink the water will also take the disease. The germs will be carried into the well. They may be disseminated from it through the entire community, and the result would be and often has been a wide-spread epidemic. This is a fact of observation and quite independent of any theory of the origin of disease. Therefore, chemical examinations of water are of value, not in that they prove that the water is unhealthful, but because they indicate the possibility of its becoming a vehicle of disease and point out the source of the contamination.

In regard to the examination of air there is much confusion as to the value of the results. I refer now to air as a vehicle of contagion, and not to its purity from a chemical point of view; and I trust no one will misunderstand my position in this regard, for there is no doubt as to the bad influence upon health of an excess of carbon dioxide, carbonous oxide, and other chemical impurities.

I maintain, however, that air which is chemically pure may be a vehicle of contagion; and that air, which is chemically very impure, may be perfectly harmless as regards contagion. In other words, sewer gas, whatever that strange combination of odors may be, is not, *per se*, a vehicle of contagion. If it were the population of New York City would be decimated every year. One of the most striking examples of a want of information concerning this subject was given last year by some of the physicians of the highest standing in New York, where the popular excitement about the danger of dirty streets was at its height. The doctors had a great meeting and foretold that there would be a great pestilence if the streets were not cleaned, and they worked themselves up into a state of excitement which frightened the people very much, and, perhaps, at the time they believed all they said. But the city escaped and the streets were not immaculate, and have not been so since.

I would not say that the health of the city was not affected by the

condition of the streets. Very likely it was; but the effect was merely that of air contaminated by the gases arising from the decomposition of refuse matter and utterly incapable of breeding a pestilence. Ammonia and sulphuretted hydrogen, and the various other gases which arise in this way do not produce contagious diseases.

But if the atmosphere carries the germs of disease it is not unlikely that these will be most active where the air is impure. For, if these be germs of living organisms they will doubtless find a suitable nidus for growth and multiplication where decomposition is going on, and they will be disseminated by the rising gases. It is very likely that some of them increase in virulence where they grow shielded from the free access of air. But so long as the germs are absent sewer gas or effluvia of any kind will not generate contagia.

About three years ago Professor R. O. Doremus read an article before the Medico-Legal Society of New York, entitled "Epidemies from a Chemical Standpoint." In the experiment which he then performed the permeability of sandstone, brick, etc., to gases was demonstrated. This fact is well known to chemists, but the experiment proves nothing more than that the poison of contagia may be retainad by the porous walls of houses. It should not be inferred, however, that the contagia are able to pass through the stone, for that has not been proved and is, indeed, highly improbable.

Experiment indicates that all the floating germs of contagious disease may be filtered from the air by means of cotton. Gun-cotton can be employed for this purpose, after which it can be dissolved and the germs will settle to the bottom of the solution where the microscopist can find them. There are also other methods of collecting them for examination. The microscopic examination of air is, therefore, very important. But it should only be entrusted to careful investigators—persons who are not too hasty in drawing inferences from experimental results. The more one studies the microbes of the air the more fully he realizes the immense field to be gone over before the results can be properly interpreted. To definitely declare the relation between these microbes and specific diseases now indicates a very superficial knowledge of the subject. For it is impossible to distinguish by sight between a bacterium that is virulent and one that is harmless.

The results of experience may therefore be summed up in a few words, thus: We have no means of determining when a water which

analysis shows is liable to become a carrier of disease does become active in its dissemination, nor can we yet determine whether the air we breathe is or is not loaded with the germs of disease.

But we cannot doubt that after years of continuous observation by competent persons satisfactory results willl be obtained. I regard it as a national misfortune that the National Board of Health has been unable to secure an appropriation adequate to continue its work and the publication of the *Bulletin.*

Skeptics may question the value of these investigations, but let us look for a moment at the actual results in saving human life, shown by the statistics of England and Wales for successive periods of ten years since 1841. The annual death-rate for those countries, for ten years, from 1841, was 22·4 in 1000 persons; for the next ten years it was 22·2, and for the next ten years, up to 1870, is was 22·5. For thirty years, therefore, it remained quite stationary. Then sanitary science was applied to diminish the death-rate, and in the next ten years, from 1871 to 1880, it fell to 21·5. This represents the saving of a quarter of a million lives. A further examination of the statistics also shows that this saving of life is in great part due to the effect of sanitary laws upon the prevalence of certain zymotic diseases. In exact figures, 0·78, or more than three-fourths of the improvement is due to this alone. The fever death-rate has fallen from 0·80 per 1000, in 1870 to 0·32 in 1880.

Another subject, upon which there is considerable misapprehension, is the efficiency of disinfectants. Here again the sanitarian can act without relying upon any theory of disease; for whether there be a living germ or a chemical poison the disinfectant must be strong enough to kill the one, or at least to render it inactive, and to decompose the other. The utter inefficiency of carbolic acid vapor, or of any ærial disinfectant whatever, in a sick-room, will be evident to any one who is familiar with the microscopic study of living germs. For it is known that they can withstand treatment with chemicals which would instantly destroy the life of higher organisms, and no atmosphere which we could breathe would destroy or materially affect the vitality or activity of disease-germs. It may be said that ordinary ærial disinfection is utterly useless. The only efficient method in the sick-room is the immediate disinfection of all refuse and thorough ventilation.

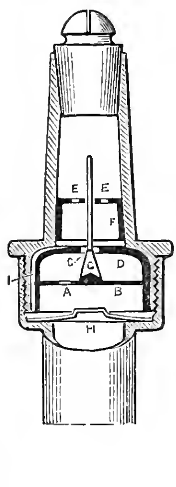
A more accurate knowledge, on the part of some persons, of the

capability of germs to resist destruction would prevent the advocacy of absurd and impracticable schemes for disinfection, such as the freezing out of yellow fever from a ship and others of like character. It may be assumed, with a fair degree of probability, that yellow fever, or any other contagious disease, will not be carried around in a ship's hold if the latter is thoroughly aired and ventilated, and by a proper regard to sanitary conditions the quarantining and disinfection of vessels, after long voyages from infected ports, would be rendered quite unnecessary.

REPORT OF THE COMMITTEE ON SCIENCE AND THE ARTS ON THE RAPPLEYE RHEOMETRIC GOVERNOR BURNER.

HALL OF THE FRANKLIN INSTITUTE,
Philadelphia, March 27, 1882.

The Committee on Science and the Arts, constituted by the Franklin Institute of the State of Pennsylvania, to which was referred for examination Rappleye's Rheometric Governor Burner, reports, that in accordance with the application, it has examined the merits of the Rappleye Governor Burner "as a device for controlling the flow and consumption of gas, and thereby maintaining a uniformity of light," and, as requested, add "an expression of opinion as to its desirability as a means of securing an economical consumption of gas."



A quantity of burners was furnished your committee for examination, from which casual selections were made, and tested with reference to the consumption of gas, and the light afforded at different pressures. A vertical section of the burner, with explanation of the cut, is appended.

A 5-foot burner, the gas being under 1 inch water pressure, consumed 4·9 feet gas per hour, and gave a light equal to 17·6 standard candles. The same burner, the gas being under a pressure of three inches, consumed 4·8 feet gas per hour, with a light equal to 16·75 candles.

A 3-foot burner, the gas under 1 inch pressure, consumed 2·95 feet gas per hour, the light being equal

to 11 candles. The same burner, under 3 inches pressure, consumed 3·2 feet gas, the light being equal to 12 candles.

Other experiments were made at the same and at a former meeting of the Committee with results not materially different. The consumption of gas by the same burner at different pressures, usually varying not more than one-tenth foot per hour, but in one instance, two and a half tenths.

The photogenic power of the city gas on the day of the above experiments, using the standard argand burner consuming 5 feet of gas per hour, was equal to 16·25 standard spermaceti candles, which is also about its average value.

Reducing the candle power in the above experiments to the rate of 5 feet consumption per hour, and comparing the same with that of the standard argand burner, we have the following results:

	Pressure.	Candle power with 5ft. gas.	Excess above Argand burner.
5 ft. burner,	1 inch.	17·95 candles.	10·40 per cent.
3 ft. burner,	3 inches.	17·45 "	7·38 "
3 ft. burner,	1 inch.	18·64 "	14·70 "
3 ft. burner,	3 inches.	18·75 "	15·38 "

The light furnished by these burners is thus seen to average 11·96 per cent. in excess of that of the standard argand burner. The flame is clear and steady, with no indication of smoke at any point above the initial pressure.

The common objection to the so-called governor burners, which merely present an unvarying check to the flow of gas, is that they require a maximum pressure to produce a fair light, while at lower pressures the light is much inferior to that of the open burner. The burner under examination meets a long felt want, in that it allows a maximum light at a slight increase of pressure above that required for an open burner, and maintains a uniform flow and light at any pressure in excess, that is liable to be encountered.

We think there is very little, if any, danger of these burners becoming impaired by use from any effect the gas may have upon them, the working parts of the governor being allowed ample room to guard against friction. The Committee has had before it satisfactory evidence, that these burners, having been in constant use for the last fifteen months, were found on examination, to be in as good condition

as when new. There need be no apprehension of condensation occurring in these burners, from the fact that the burners while in use, being of a higher temperature than the gas, preclude the possibility of such condensation. If the case should occur that the burner occupies a point lower than the supply pipe leading to it condensation in the pipe might drip down into the burner. The light powdery deposit sometimes found would not interfere with the action of this governor.

In consideration, then, of the uniformity of gas consumption maintained by this burner under varying pressure, and its high photogenic qualities, we recommend it with confidence as affording a better light, at less expense, than any other practical appliance with which we are acquainted.

The above report was adopted at the stated meeting of the Committee on Science and the Arts, held May 3, 1882.

WILLIAM H. WAHL, *Secretary.*

THE SILVER AND GAY DYNAMOMETER.

By LUTHER H. SARGENT.

The dynamometer herewith illustrated is made by Messrs. Silver & Gay, North Chelmsford, Mass., and is designed to meet the requirements of mechanical engineers and others who have occasion to determine the actual amount of power required to operate machinery. It is upon the principle of one invented by the late Samuel Batchelder, called by him the Balance Dynamometer, which was described and illustrated in the JOURNAL of the FRANKLIN INSTITUTE, vol. 36, page 275, *et seq.* (October, 1843). It is made from new patterns, designed to combine such improvements and additions as will secure accuracy, convenience, and durability.

Referring to Fig. 1, the counter shaft, to bring the driven and driving pulleys into the same vertical plane, and the dash pot, to steady the scale-beam, both first applied by Mr. J. B. Francis, add much to convenience in placing and operating. The arrangement of the dashpot stand and scale-beam, so that they may be used on either side, is for convenience in placing and to avoid crossing belts. The trucks, upon which the machine may be supported, make it easy to move and

to adjust in position. The speed indicator (Fig. 2) may be thrown into, or out of gear, at pleasure, and will indicate the number of revolutions in the interval. The scale-beam and plate-weight, on the size

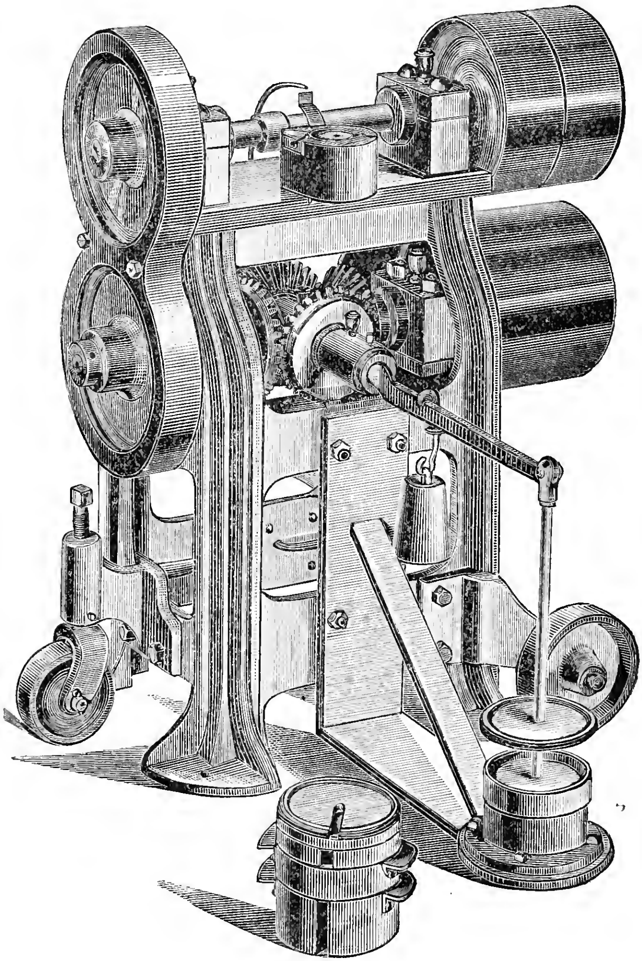


Fig. 1.

illustrated, are figured to indicate the force exerted at a point which, if revolving around the axis of the shaft, would describe a circle three feet in circumference.

The position of the hook-weight on the beam (balanced when at the

zero notch) will indicate by tenths of a pound, up to twelve pounds, the weight raised three feet to a revolution, and the plate-weights, when placed in the pan, will indicate, as figured, 5, 10, 25, 50, and 100 pounds, raised three feet to a revolution.

With the speed at 1000 revolutions per minute, and resistance requiring all the weights (202 lbs.) to keep the beam in a horizontal position, the result would be

$$\frac{202 \times 1000 \times 3}{33,000} = 18\tfrac{4}{11} \text{ H.P.}$$

When W represents weight, and R revolutions per minute.

$$W \times R \times 3 = \text{foot pounds, and}$$

$$\frac{W \times R}{11,000} = \text{horse-power.}$$

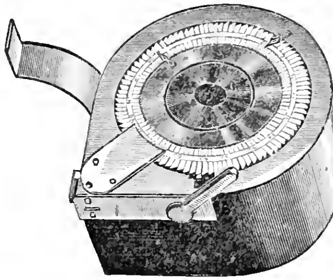


Fig. 2.

The pulleys are three feet in circumference, so that the weights indicate also the force at their surface, or the strain on the belt. The size illustrated is capable of transmitting and weighing the power requisite to operate any machinery which can be driven by a belt four inches wide, running three thousand feet per minute.

THE AMERICAN IRON TRADE IN 1881.

The annual report of Mr. Swank, the Secretary of the American Iron and Steel Association, for the year 1881, has just been issued, and as usual is a document of more than ordinary value to those who are interested in the leading industry of our country. We present below a brief summary of the leading statements and facts which it contains.

The Secretary makes the remark at the outset of his report that the prosperity which was restored to the American iron trade in 1879, and which was continued in 1880, attained its highest development in 1881, which year he records as being the most prosperous one that American iron and steel manufacturers have ever known, as regards production, with the exception of the single item of iron rails; the output of 1881 was greater for every article enumerated in the

appended table, than in 1880, or in any previous year of our history. Another forcible feature is the fact that our importation of iron and manufactured products during the year 1881 fell off very considerably from the proportions they had assumed in 1880, when they reached the highest figures known in the history of the iron trade.

During the past year California, Colorado, and Washington Territory entered the field as producers of iron.

The total number of iron furnaces in the United States in 1881 is estimated to be 716, of which, at the close of the year, 455 were in blast and 261 out of blast. As regards the kind of fuel used, the active furnaces are nearly equally divided between bituminous, anthracite and charcoal.

The Bessemer steel industry is reported to be in a very flourishing condition. The production of Bessemer steel ingots, in 1881, amounted to 1,539,157 net tons, an increase of 335,984 tons over that of 1880, or 28 per cent. The strong and gratifying growth of this branch of the trade is clearly shown in the following tabulation.

Years.	Net tons.	Years.	Net tons.
1872	120,108	1877	560,587
1873	170,652	1878	732,226
1874	191,193	1879	928,972
1875	375,517	1880	1,203,173
1876	525,996	1881	1,539,157

Bessemer steel ingots were produced by thirteen works in 1881, of which seven are in Pennsylvania. Two new works, both in Pennsylvania, produced Bessemer steel for the first time in 1881. These were the Pittsburgh Bessemer Steel Company, limited, located at Homestead, near Pittsburgh, having two converters; and the Pittsburgh Steel Casting Company, of Pittsburgh, with one converter. Since the close of the year one new works has been completed and put into operation, namely, that of the Colorado Coal and Iron Company, located at South Pueblo, Colorado, which made their first blow on April 11, 1882. Besides these, two more Bessemer works, one at Scranton, Pennsylvania, and another at Chicago, are expected to go into operation before the close of the present year. The thirteen complete Bessemer works in the United States have thirty-three converters. The production of Bessemer steel rails in the United States,

during the two years (1880 and 1881), exceeded that of Great Britain.

The production of crucible steel ingots in the United States, in 1881, was 89,762 net tons and of open-hearth steel ingots, for the same year, 146,946 net tons. The production of all kinds of steel, in 1881, reached the unprecedented figure of 1,778,912 net tons. When it is recalled to mind that our collective production of steel in 1872 was only 160,108 net tons, the enormous figures of 1,778,912 for 1881 reveal the unexampled growth of this branch of the trade. Mr. Swank, in commenting upon these facts adds, that "they undoubtedly record the greatest metallurgical achievement ever accomplished by any country."

The number of miles of new railway constructed during 1881, reached the unprecedented figures of 9650 miles. It exceeded any record we have ever before made in any one year. The year 1871 contributed the next best record, 7379 miles, and the year 1880 the next, 7174 miles.

Without entering into the details respecting other items of the iron trade, which would unduly extend our review of Mr. Swank's valuable report, we will add, in conclusion, the following summary, which will be found useful for future reference, viz.:

Grand Summary of U. S. Statistics for 1881.

Production of pig iron in 1881, net tons,	4,641,564
Production of spiegeleisen in 1881 (included in pig iron), net tons,	21,086
Production of all rolled iron, including nails and excluding rails, in 1881, net tons,	2,155,346
Production of cut nails and spikes in 1881, included in all rolled iron, kegs of 100 pounds,	5,794,206
Production of Bessemer steel rails in 1881, net tons,	1,330,382
Production of open-hearth steel rails in 1881, net tons,	25,217
Production of iron and all other rails in 1881, net tons,	488,581
Total production of rails in 1881, net tons,	1,844,100
Production of crucible steel ingots in 1881, net tons,	89,762
Production of open-hearth steel ingots in 1881, net tons,	146,946
Production of Bessemer steel ingots in 1881, net tons,	1,539,157

Production of all kinds of steel in 1881, net tons, .	1,728,912
Production of blooms from ore and pig iron in 1881, net tons, ...	84,606
Imports of iron and steel in 1881, . .	$61,555,078
Exports of iron and steel in 1881, . .	.$15,782,282
Imports of iron ore in 1881, gross tons, . .	782,887
Production of Lake Superior iron ore in 1881, gross tons,	2,336,335
Production of iron ore in New Jersey in 1881, gross tons,	737,052
Total production of iron ore in the census year 1880, net tons, ...	7,974,705
Production of anthracite coal in the census year 1880, net tons, ...	28,646,795
Production of bituminous coal in the census year 1880, net tons, ...	42,420,581
Production of anthracite coal in 1881, gross tons, .	28,500,016
Miles of railway completed in 1881, . .	9,650
Miles of railway in the United States, December 31, 1881	103,321
Iron ships built in the United States in the fiscal year ended June 30, 1881, . . .	42
Net imports of foreign merchandise into the United States in the ten months ended April 30, 1882, .	$579,462,510
Exports of domestic merchandise, out of the United States, in the ten months ended April 30, 1882 .	635,867,349
Net imports of specie into the United States, in the ten months ended April 30, 1882, . . .	35,895,247
Net exports of specie out of the United States, for the ten months ended April 30, 1882, . .	22,708,081
Immigrants into the United States, in the calendar year 1881, ...	720,045

W.

The Tunnel Under the English Channel.—One of the experimental galleries of the submarine tunnel between France and England is nearly completed. The whole length of the tunnel will probably be about thirty-two kilometres (19·884 miles). It is thought that about one-tenth of this length will be ready for examination within a few weeks.—*Les Mondes.* C.

Photographs of Flying Birds.—M. Marey has succeeded by instantaneous photography and with the help of a photographic revolver similar to the one which was contrived by Jansen for observing the transit of Venus, in obtaining a complete analysis of different forms of locomotion, including the flight of birds. More than two years ago Muybridge obtained fine pictures of running horses, which were photographed in $\frac{1}{500}$ of a second. He also photographed flying pigeons but could only get a single picture. Marey has been able to obtain a dozen successive pictures in a second, each exposure requiring only $\frac{1}{700}$ of a second. By arranging the pictures in a phenakistiscope the appearance of the flying bird may be reproduced under conditions which permit the analysis of different phases of the wings.—*Chron. Industr.* C.

New Process in Sulphur Mining.—Messrs. de la Tour du Breuil, having been engaged for ten years in the direction of sulphur mines in Sicily were struck by the great loss involved in the ordinary process of separating the sulphur from its gangue. The idea occurred to them to increase the heat of the boiling water by the presence of a salt which it holds in solution. They fixed upon chloride of calcium on account of cheapness and the uniformity with which it maintains a temperature of 120° (248° F.). The bath contains 65 per cent. of chloride of calcium and can serve indefinitely. The apparatus consists of two rectangular vats which are coupled and inclined at an inclination of ten per cent. As soon as the operation is terminated in one of the vats the boiling liquid is drawn into the other which has been previously filled with the ore. While the solution is going on there, which requires about two hours, the first vat is emptied and recharged; hence there is no interruption in the work and the bath is never cooled. A single fire is sufficient for the two vats, the heat being turned alternately from one to the other. This process presents the following advantages: 1. A cheap extraction of the sulphur, the cost being only about $1 per ton; 2. Great purity, analysis showing only $\frac{1}{20}$ of 1 per cent. of earthy residue and no trace of sulphurous or sulphuric acid; 3. Possibility of operating during the whole year since there is no production of sulphurous acid, which is so injurious to the public health and to agriculture.—*Comptes Rendus.* C.

Resources of Algiers.—Algiers abounds in deposits of copper, silver bearing lead, zinc, and especially iron. The Mokta mine yields 1800 tons of iron ore per day. Materials for construction, building stones, lime, plaster, marble, etc., are abundant. Salt is found almost everywhere. Mineral springs are very numerous. The number of workmen employed in the mines already exceeds 3500. The principal agricultural products are cereals and dry legumes. The cultivation of tobacco has increased largely since 1867. The greatest future expectations are based upon the culture of vineyards; the extent of land devoted to vines already exceeds 20,000 hectares (49,423 acres). The public works have already reached considerable importance. There are 10,506 kilometres (6528 miles) of highway, and 1282 kilometres (796·6 miles) of railroads under construction.—*Chron. Industr.* C.

Tempering by Compression.—L. Clemandot has devised a new method of treating metals, especially steel, which consists in heating to a cherry red, compressing strongly and keeping up the pressure until the metal is completely cooled. The results are so much like those of tempering that he calls his process tempering by compression. The compressed metal becomes exceedingly hard, acquiring a molecular contraction and a fineness of grain such that polishing gives it the appearance of polished nickel. Compressed steel, like tempered steel, acquires the coercitive force which enables it to absorb magnetism. This property should be studied in connection with its durability; experiments have already shown that there is no loss of magnetism at the expiration of three months. This compression has no analogue but tempering. Hammering and hardening modify the molecular state of metals, especially when they are practiced upon metal that is nearly cold, but the effect of hydraulic pressure is much greater. The phenomena which are produced in both methods of tempering may be interpreted in different ways but it seems likely that there is a molecular approximation, an amorphism from which results the homogeneity that is due to the absence of crystalization. The advantages of the new method are obvious. Being an operation which can be measured, it may be graduated and kept within limits which are prescribed in advance; directions may be given to temper at a specified pressure, as readily as to work under a given pressure of steam.—*Chron. Industr.* C.

Thermal Laws of the Exciting Spark.—Villari calls the exciting spark of the discharge of a condenser the one which is produced against the exciter; the one which is formed in a break of circuit he calls the conjunctive spark. He deduces from his experiments the following laws: 1. The heat of the exciting spark increases more rapidly than the third power of the charges for a small potential. 2. It increases as the squares of the charges for a mean potential. 3 It increases nearly in the ratio of the charges for a very high potential. When the potential remains constant the heat of a single exciting spark increases a little less rapidly than the charge. In varying the potential of a constant charge which he had accumulated in a variable number of jars he found that the heat of a single exciting spark increases more rapidly than the potentials when they are small, like the potentials when they are mean, much less than the potentials or even decreasing when the potentials increase if they are very high.—*Comptes Rendus.* C.

Spontaneous Galvanization.—M. P. Paul, Civil Engineer, records a curious accident which happened in the workshop of M. Fleury. The feed-water produced thick incrustations and the proprietor was advised to put fragments of zinc into the boiler. After a few days, in spite of the greasing, the machinery began to act sluggishly. The piston began to grip, and in a few days more it was almost impossible to make it move. The pump was then dismounted and the piston was found covered with a thick layer of adherent copper. It was put upon the turning lathe and in some places, which had been made elliptical by wear, the layer was so thick that the turning was made in pure copper. The following explanation is given. The boiler was connected with the engine by copper tubes. The particles of zinc which were carried in the steam formed with the tubes an immense number of small galvanic couples. The piston principally attracted the copper, both on account of its own continual movement exercising an attraction of mass upon the molecules, and on account of the heat which facilitated their permanent deposit. The result seems to show that the temperature of 144° to 150° (291·2° to 302°F.) was particularly favorable to the production of the phenomena. It is probable that the electric properties of the steam also aided in its development.—*Genie Civil.* C.

Electrified Lily.—During a storm at Montmaurin, in the upper Garonne, M. F. Laroque witnessed a curious electric phenomenon. Looking towards a clump of lilies, he saw the highest plunged in a diffused violet light which formed an aureole around the corolla. This light lasted for 8 or 10 seconds. After it had ceased he approached the lily, which he found, to his great surprise, wholly deprived of its pollen, while the neighboring flowers were covered with it.—*La Nature.*

Evaporation in Circular or Elliptic Basins.—If a liquid body sends vapor into an unlimited atmosphere there will proceed from each element of its surface, during a unit of time, a quantity of vapor proportional to an electric charge which is present and in equilibrium upon the element. The lines of the vapor currents correspond to the lines of electric force, and the surfaces of equal vapor pressure to the surfaces of equal potential. The electric equilibrium of an infinitely small circular or elliptic plate is the electrostatic analogue of the problem of the evaporation of a liquid contained in a basin of circular or elliptic contour.—*Les Mondes.* C.

Mummied Plants.—Dr. Schweinfurth has examined the garlands which covered the breast of the mummy of King Ahmos 1st, which was one of the most important treasures in the great discovery at Deir el Bahari. The garlands are composed of leaves of the Egyptian willow, *Salix safsaf,* folded twice and sewed side by side along a date branch, so as to form clasps which enclose isolated flowers of *Acacia klotica, Nymphæa cærulea, Alcea ficifolia,* and a *delphinium,* which he thinks to be Oriental. The garlands of other kings contain flowers of *Carthamus tinctorius,* and the leaves which are woven in clasps are those of the *Mimusops kummel.* Leaves have also been found in the coffin of Neb Seni, a high priest of the twentieth dynasty, of the *Cucumis citrullus* These leaves and flowers date from some centuries before the epoch of the Trojan war; Dr. Schweinfurth has preserved a great number of them, by moistening them, then putting them in alcohol and afterwards expanding them and drying them, so as to form a small herbarium of plants that are thirty-five centuries old. The color of the chlorophyll is remarkably preserved, being violet in the delphinium and green in the cucumis.—*Les Mondes.* C.

Action of Stannic Salts upon Animal Matter.—When silk is steeped in a solution of stannic chloride and then thoroughly washed in order to remove the excess of uncombined salt it is found to have increased in weight and to have absorbed a quantity of stannic oxide proportioned to the concentration of the solution and the length of immersion. If the silk is then passed into boiling suds, washed and replunged in the bath it fixes a new quantity of tin and by repeating these operations its primitive weight may be doubled. This furnishes a ready method of loading silk with a colorless oxide, in order to receive a permanent dye of any hue that may be desired. The weight of silk which has been thus loaded with stannic oxide may be increased still more by putting it in a solution of any tannic material. This cannot be done, however, where delicate shades are required, because the impurities of the tannin produce a muddy tint. Skins which are treated with solutions of bichloride may be tanned in a very short time.—*Bull. de la Soc. Indust.* C.

Grafting Bones.—The experiments of Ollier, in transplanting bones upon rabbits have been received with considerable doubt by Wolf and others. W. MacEwen reports the case of a patient who had necrosis of the humerus which had destroyed considerable portions of the periosteum. He had occasion to operate upon several subjects with anterior curvatures of the tibia from whom he removed wedge-shaped portions of bone in order to straighten the bent limbs. These portions, with their periostium, were divided into numerous small fragments which were immediately placed in a channel prepared to receive them in the diseased arm. These small portions gradually united, adhering to the summit of the humerus on one side and to the condyles on the other, and finally forming a solid shaft about half an inch shorter than the humerus of the opposite arm. In this way a useless arm was rendered perfectly serviceable. The transplanted portions were taken from six different limbs, with their periosteum and their marrow, and placed in the arm of a young lad, in an intermuscular space which was freshly opened by the scalpel in order to receive them. The grafts not only remained entirely in the tissues, but they formed a perfect union with one another, making in all four and a half inches of bony transplanting in which formed a new humerus that can be used as well as that of the other arm.—*Comptes Rendus.* C.

Lincrusta.—Frederick Walton, the inventor of Linoleum, has introduced a new article, under the above name, for the purposes of plastic decoration. It consists of a compressed mass of cellulose, paper, cork, etc., thoroughly impregnated with oxidized linseed oil and resin. The mass is at first doughy, so that it can be spread or pressed in thin or thick sheets or moulds. It becomes gradually leathery, pliable, elastic, tough, not affected by water or by the influences of the weather, and is a bad conductor of heat. It is much cheaper than pressed leather or its papier maché imitations, and can receive much deeper, sharper and more lasting impressions. Lincrusta tapestries, with decorations in imitation of ivory, gold, silver, bronze, etc., can be furnished at about one-fifteenth the price of leather.—*Der Techniker.*

Electric Currents Produced by Distant Lightning.—In 1826 M. D. Colladon published an account of disturbances of his galvanometer by a storm, which was so far from Paris that no clouds were visible within 30 degrees from the zenith. Peclet, in his *Traité de Physique*, gives a note upon Colladon's observations in which he says: "During a storm the needle of the galvanometer is in continual motion; each flash is immediately followed, sometimes even preceded, by a sudden change in the direction of the deviation, or by a violent increase. In some cases the deviation passes instantly from the positive to the negative maximum, or inversely; these effects continue even when the flashes are two or three leagues off, provided the air is very damp and the sky covered with clouds." In 1879 M. Renè Thury, son of a professor in the University of Geneva, stretched a copper wire horizontally between two houses, at the height of the roofs and communicating with the earth by means of water pipes. Two telephones were connected with the wire, one of which had a resistence of 4·5 ohms, the other of 2·5 ohms. In every thunder storm the flashes of lightning have always been accompanied by a very characteristic crackling in the telephones. This noise is heard at the same instant that the flash is seen, whatever may be its distance, and results, consequently, from the induction of the distant discharge upon the wire. Every flash which is visible to the eye is heard in the telephone, even when it is so distant that there is no audible thunder.—*Comptes Rendus.* C.

Melting Steel by Electricity.—Dumas recently exhibited to the French Academy an ingot of steel, which Siemens had melted by an electric current in a crucible of magnesia at the Palais de l'Industrie, in the British section of the Exposition. The fusion was completed in 14 minutes, requiring for the supply of the electrodynamic machine a less expenditure of coal than would have been needed for the direct melting in an ordinary furnace.—*Comptes Rendus.* C.

New Determination of Jules' Equivalent.—Cantoni and Grosa have determined the mechanical equivalent of heat by a series of experiments in which they substituted mercury for water. Its great thermal conductibility and the relative invariability of its specific heat at the low temperatures which they employed induced them to make the substitution. The method of experimenting consisted in the sudden arrest of a mass of mercury, falling from a given height and consequently provided with a known amount of dynamic energy. The increase of temperature at each experiment was carefully measured and the dynamic equivalent of a calone deduced by a simple calculation. The mean of all the results is almost precisely the same as that which Joule obtained from his most satisfactory experiments. The agreement of the values which are furnished by two processes that are so distinct seems to give complete assurance of the accuracy of the results.—*Acad. dei Lincei.* C.

Book Notices.

Bi-Centennial Souvenir: Philadelphia, What it is. Philadelphia Insurance Guide. J. H. C. Whiting. Review Publishing and Printing Co., Philadelphia, 1882. Price, 50 cents.

This is a pamphlet, in two parts, of 72 pages, giving first a brief view of the early history of the city, then a more extended but succinct description of its present immense industrial development. The second part is a convenient and portable guide or directory to all the insurance companies, agents and brokers thereof, in the city, together with a history of the commencement and struggles of insurance in the provinces and afterwards in the United States. As shown therein, it was in Philadelphia that marine and fire insurance were first practiced and developed on this continent. It can safely be stated that the

above named is the most concise and forcible presentation of the advantages for residence and the manufacturing greatness of Philadelphia that has yet been published. The chief features and arrangements of the city and environs, prominent buildings, railroads, bridges steamships, institutions, and chief industries mentioned by names, are given in a form easily grasped and retained by the memory. The first part concludes with a grouping of terse facts and data astounding in their magnitude. One seems to be reading of a second London; and truly the resemblance is great—if not fully as to population, certainly in extent, location, arrangements, and grandeur of edifices; also as the place of commencement in the Union of all the chief elements of national strength and metropolitan greatness. The directory for insurance companies, agents and brokers could not well be improved, and must be seen to be appreciated.

We have been especially interested in the plain showing made in this work—accompanied by data, tables, etc.—that the industries of Philadelphia have been much underrated in the census of 1880. In some preliminary data published from that document—though thereby it is conceded that the amount of capital invested in manufactures in Philadelphia exceeds that of any American city—yet in value of productions she is rated as second, whilst at the same time it is announced, just preceding the table, that the capital and annual value of productions of such great interests as brewers, distillers, and others, whose productions would count many millions of dollars annually, are not yet ready, and not included in the tabulation. Doubtless the latter is believed to be final by most persons, for the explanatory note is not at all prominent.

[In this connection we think we are not indiscreet in stating that Mr. Lorin Blodget—working in co-operation with the city authorities and the leading manufacturers and scientific and mechanical institutions—is collecting unimpeachable statistics by which he will prove, in lectures before the Franklin Institute in November, that the annual value of Philadelphia industries is nearly double the amount accorded to them in the census of 1880.]

It is also an interesting fact, shown in this volume, that although Philadelphians must lament the departure of much of the former European, Indian, and China trade, which made their city the commercial emporium of the United States until about 1830, the tonnage

of its numerous coastwise and collier vessels alone exceeds by more than 300,000 tons that of all American vessels in the United States engaged in the foreign trade. While, from this volume, many citizens will learn and remember more than ever before of the extent, wealth, and vast industries of the place of their birth or adopted residence, the Franklin Institute can feel a vivid pleasure in the recital of the present greatness of a city which Franklin loved to call "Dear Philadelphia"—a city which, though in his day small in population, performed deeds of wonder in moulding the destinies of the nation and in promoting science and the mechanic arts. N.

THE WEST, FROM THE CENSUS OF 1880. By Robert P. Porter.

A robust and handsome volume, published by Rand, McNally & Co., of Chicago, with the above title appears to be an appropriate contribution to the present demand for recent and authentic information as to the resources and development of the Western States and Territories. Mr. Porter is a prolific writer, and having the census returns for 1880 at his command, in advance of their official publication, he has used them with effect in completing statistical comparisons for the Western States on almost every possible subject—population, agriculture, manufactures, social and sanitary statistics, debt, taxation, revenue, etc. The value of such a compilation is great if faithfully made, as this appears to be, and perhaps for the first time it is made complete for a group of States in their natural association. Mr. Porter acknowledges valuable aid from Henry Gannett, Prof. W. P. Jones, Dr. Henry Randall, and Prof .James H. Blodget, and it is evident that the body of the volume covering the history and specific description of soils, climate, social condition, and progressive development of these States has been very carefully written. The various parts of the work should have been separately credited to identify the share of each author and to give proper credit for the historical, descriptive, and scientific portions.

The defects of the present census on many of the business and crop statistics detract much from the value of the work. The live stock, sheep, cattle, etc., are not much more than half covered, the deficiency being greatest in Kansas, Nebraska, Montana, and the territories generally, precisely where information is most desired. The entire class of returns taken by personal canvassers, except mere population, is

more defective in the census of 1880 than at any former period, the errors arising from haste, misdirection, and lack of competence of the persons employed. The errors are all on the side of deficiency, or omission, and range from thirty to fifty per cent. in most cases, especially for agricultural and industrial products. There is no danger that the public will get an exaggerated estimate of the productive capacity of Kansas, Nebraska, or Colorado from the figures here given as the most recent on these subjects. These figures, as for corn, wheat, cattle, sheep and wool, hogs and hog products, etc., are each fully twice as great for 1882 as are here for 1880. Mr. Porter should have given some indications of these recent facts, especially for the benefit of those who, in Europe, are likely to take the census of 1880 as authority until the current decade ends with 1890. In the ordinary measure of time 1882 is already more than half a decade in advance of 1879–80—really 1879 for these Western States. But on the whole, the value of this as a work of reference for the Western States is great, and it is one that has been needed for some time.

Some errors are noticeable even in the hasty review now made, as, at page 199, where the mean temperature of Lansing is given at 49·1° and that of Detroit 45·5°; neither can be correct. Also, "the distribution of the rainfall throughout the seasons is, for the upper peninsula, 19 inches for the spring, 27 inches for the summer, 27·3 for the autumn, and 19·1 for the winter"—we quote exactly. This would be a total rainfull of 92·4 inches for the year, and if the quantities were not stated in words we should think it a misprint of figures only. The annual quantity is 30 inches. We also notice that the ink used in printing on the fine paper used for the book has not yet penetrated sufficiently to stay under the touch of the careless hand, a suggestion to readers as well as to the printers. L. B.

House Drainage and Sanitary Plumbing. By Wm. Paul Gerhard, Civil and Sanitary Engineer. Newport, R. I.

The figures and charts which give statistical information relative to the "ills that flesh is heir to" are uninteresting to the general public if they stand alone, unaccompanied by anything calculated to furnish a key to the intelligent and comprehensive understanding of the cold tabulated facts. This condition of things is most undesirable, inasmuch as it is of the utmost importance that the general public should

not only recognize the value of such statistics, but should be able to take a lively interest in them, and to appreciate their full significance.

Nothing could be better adapted to the attainment of this desideratum than the annual reports now published by the State Boards of Health that have been established in at least four of the United States —Massachusetts and Michigan took the lead in this matter, and New Jersey and Rhode Island have followed—and it is from the Fourth Annual Report (being that for the current year) of the last-mentioned State that the work under consideration is a reprint.

It is a lamentable fact that had such advice as is contained in this pamphlet been universally acted upon in the past, and continued to be acted upon now, much of the ill-health that exists among civilized peoples would not be; several common and serious diseases might have been almost if not entirely eradicated, and many premature deaths would not have occurred. The evidence is overwhelming; but as this is not the place for its consideration, it must suffice to say that where sickness is not directly traceable to sanitary defects, the sequence of cause and effect may be established indirectly, and sometimes perhaps only inferentially, through the medium of heredity or contagion.

It is gratifying to be able to state that there are signs that the time is rapidly approaching when there will be a competition among cities and towns in the reduction of their respective death-rates to a minimum, particularly with respect to those diseases which are most conclusively shown to be associated with bad drainage.

The writer of the work before us claims that it is "the outgrowth of much study and experience." It has the merit of being eminently practical and amply illustrated, and comprehends more valuable information upon the subject it treats of than we recollect to have seen in a work of the same size. W. B. C.

Franklin Institute.

HALL OF THE INSTITUTE, October 18, 1882.

The meeting was called to order at the usual hour, with the President, Wm. P. Tatham, in the chair.

There were present 115 members and 6 visitors.

The minutes of the last meeting were read and approved.

The Actuary submitted the minutes of the Board of Managers, and reported that at the stated meeting, held Oct. 11th, 8 persons had been elected members.

The Secretary, from the Committee on Science and the Arts, reported, by instruction, that the Committee, after full investigation, had reported a recommendation for the award of the Scott Legacy Medal and Premium to the Pratt & Whitney Co., of Hartford, Conn., for their Standard Gauges, Taps and Dies, and to Henry R. Heyl and Hugo Brehmer, of Philadelphia, Pa., for their Wire Book-Sewing Machine. He reported also that the above recommendations had been duly advertised for three months, and that no objections had been offered to the recommendations.

It was decided, on motion of Mr. Hector Orr, that the recommendations of the Committee on Science and the Arts be approved, and that the Secretary be directed to notify the Committee on Minor Trusts of the Board of City Trusts, of the action of the Institute.

Mr. C. J. Hexamer, from the Special Committee on the Prevention of Fires in Theatres, reported progress, and the Committee was continued. Similar report was made and similar action taken, in regard to the Special Committee on Memorial to Mr. Briggs.

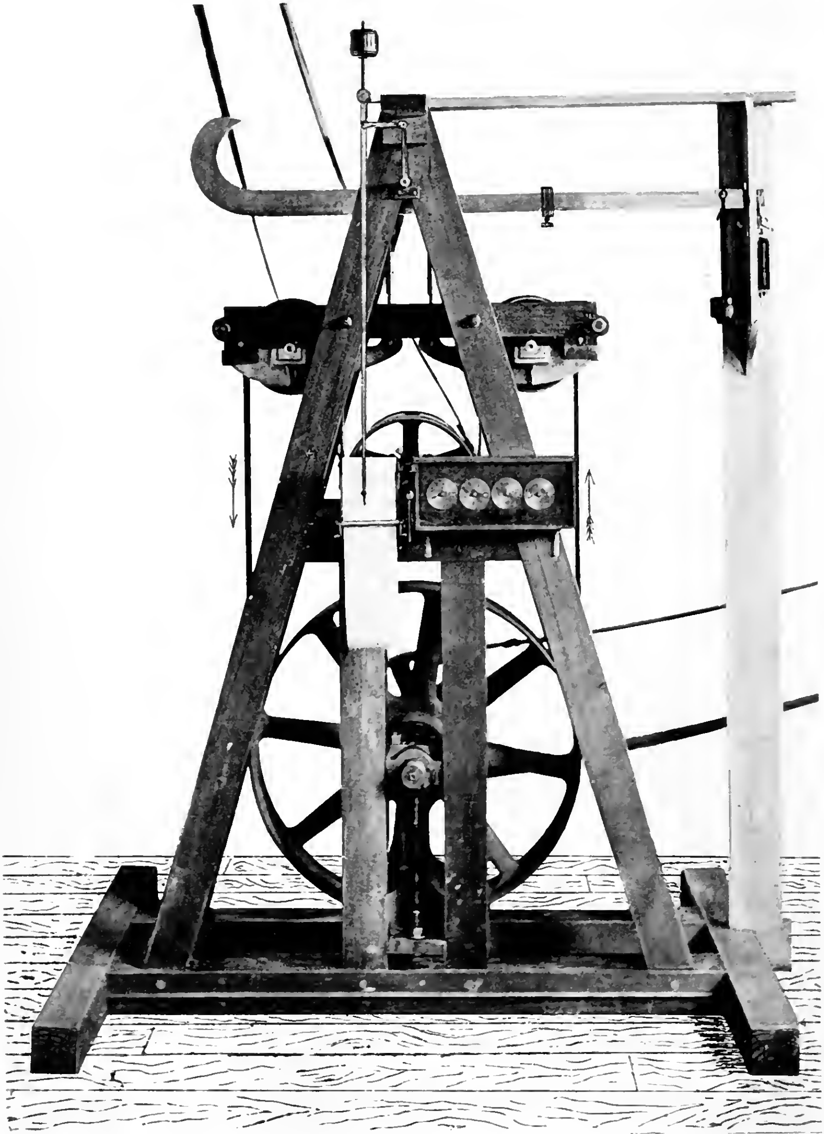
The Secretary's report included a description of the Edison Electric Lighting System in New York, and a detailed account of the Cable System of Street Railways. The latter subject was very fully discussed by Messrs. Heyl, Freeman and Shaw. The following mechanical inventions were also shown and described: Pohl's Differential Car Starter; Spratt's Improved Mercury Seal Trap; Addis' Fire-escape; Avery's Anti-friction Bearing, and De Beaumont's Condenser.

Mr. E. Mallett, Jr., of New York, next read a paper entitled "Experiential Principles of Controlled Combustion," describing certain peculiarities of furnace setting and operation.

The paper provoked an animated discussion, which was participated in by Messrs. Shaw, Strong, Grimshaw, Henderson, Ronaldson, and the author. The paper has been referred to the Committee on Publication.

The meeting was thereupon adjourned.

WILLIAM H. WAHL, *Secretary.*



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TATHAM'S DYNAMOMETER.

JOURNAL

OF THE

FRANKLIN INSTITUTE.

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXIV. DECEMBER, 1882. No. 6.

AN IMPROVED DYNAMOMETER.

By WILLIAM P. TATHAM.

The FRANKLIN INSTITUTE JOURNAL for November, 1881, contains a description of a belt dynanometer involving the application of a new principle. Two forms of the machine were described and illustrated and a third form briefly indicated.

This third form has been developed and a dynanometer has been constructed for the use of the Franklin Institute, as represented in the annexed print from a gelatine plate produced by the beautiful photographic process employed by Mr. F. Gutekunst of this city.

This machine consists of a double gallows frame constructed of wood, framed together at the foot and sustaining at the top a cross block, from which the scale beam is suspended. This beam (by Fairbanks & Co.) is of bright steel, capable of weighing 300 lbs. and graduated to 25 lbs. by pounds and tenths, the pound marks being ·95 inch apart.

When the indicator is employed, a spring balance is attached near to the extreme end of the beam so as to exhibit 25 lbs. by pounds and tenths.

From the principal centre of the beam to the extreme right hand

end is $32\frac{1}{4}$ inches, measuring on the print $1\frac{7}{8}$ inches. The scale of the print (where applicable) is therefore 1 to 17·2.

On each side of the principal centre of the beam and 1·9 inches therefrom (unseen in the print) are knife edges, from which hang two links suspending the free moving ends of two cast iron lever frames, whose fulcrums are outside knife edges, which rest upon two iron plates bolted to the gallows frames.

Each of these lever frames carries a pulley, whose face is 7 inches and circumference $27\frac{3}{32}$ inches high and 27 inches low (measured by a thin steel tape) from which we deduce the average radius of 4·30375 inches.

The axis of the pulley is placed 8·78 inches from the link knife edge and 4·39 inches from a line joining the fulcrum knife edges. The effective radius of the pulley is found by experiment to be 4·387256 inches.

The middle pulley, partially obscured by the counter and indicator card, represents the machine on trial.

Its shaft (diminished) is produced towards the observer, and by means of a clutch and sleeve carrying a small spur wheel and worm screw, the counter and card are put in, or out of gear at pleasure. The shaft, produced towards the rear, carries an outside pulley and may be coupled directly to the machine on trial, or connected with it by a belt.

The middle pulley has a face of 7 inches and a circumference of of $38\frac{3}{4}$ inches high and $38\frac{7}{16}$ inches low, or an average circumference of 38·59375 inches. Careful measurements showed that the actual delivery of belt per revolution was 39·595 inches, or about ·005 inch less than the 3·3 feet desired.

The larger lower pulley is the driver on the first motion shaft. It is about 30 inches diameter and 7 inches face. It is on a shaft which receives power from an outside source, and runs in journals on a frame, adjusted vertically in slides, by means of set-screws, so as to tighten the belt.

The belt is about 16 feet long, 6 inches wide, $\frac{2}{9}$ of an inch thick, of oak-tanned leather. The splices are scarfed, glued and riveted, so as to preserve a uniform thickness.

The flesh side of the belt is next the driving pulley and next the two idler pulleys on the lever frames, and the hair side is next the upper middle pulley.

The belt runs in the direction of the arrows on the outside, down on the left and up on the right. But in describing its operation, it is best to follow the tension of the belt in a direction contrary to the motion of the belt itself.

The tension, originating at the lower driving wheel, acts vertically upon the left hand idler pulley at the extremity of its effective radius and in a line joining the two knife edges of the fulcrum, and therefore the effect of this part of the belt upon the scale beam is *nil.*

Losing enough force to overcome the friction of the idler pulley, the remaining tension acts vertically; *first,* by reaction upon the lever frame carrying the idler pulley, at a point corresponding to the extremity of the inside effective radius of the pulley, and thence through the link, upon the positive side of the scale beam; and *second,* upon the middle pulley representing the machine on trial. These forces are equal and opposite.

The tension, acting upon the middle pulley, there performs the work which is to be measured and is reduced thereby. The remainder acts, *first,* by reaction on the middle pulley, and *second,* directly upon the lever frame carrying the right hand idler pulley as before, and thence through the link to the negative side of the scale beam. These two forces are equal and opposite.

The tension then passes over the idler through the fulcrum, as before, to the place of beginning. The outside slack tension has therefore no influence on the scale beam.

It is evident from this description that the only forces bearing upon the scale beam are the tension of the tight belt on the positive side of the beam and the tension of the slack belt on the negative side. The scale beam therefore weighs the difference between the two.

To estimate the power absorbed by the machine on trial, multiply the number of pounds exhibited by the scale beam, by the number of revolutions of the middle pulley exhibited by the counter, and divide the product by 10,000. The result is horse-power and decimals.

The principal centre of the scale beam is lengthened towards the observer, and at its nearest extremity carries a vertical lever arm attached to a horizontal link connecting it with a long vertical index lever, which carries a pencil at its lower end, moving horizontally as the end of the beam vibrates vertically. This pencil marks upon a a ribbon of paper, caused to move vertically between two revolving rollers, which are driven by the worm screw upon the prolongation of

the shaft of the middle pulley before mentioned. One hundred revolutions of this worm cause one revolution of the worm wheel upon one of the rollers.

The scale beam being attached to a spring balance when the indicator is used, the ordinates of the curve traced by the pencil, plus the weights hanging on the scale beam, will represent the force employed, while the abscissas will represent the motion.

Of course, the line traced by the pencil will be a zigzag. As far as this results from the nature of the spring and from variable resistance, it is inevitable. But it also results from imperfections of belts and pulleys, which may be avoided. If the pulleys are perfectly round and balanced, and if the belts are perfectly even in thickness and quality, so much of the trembling will be avoided that there will be no necessity for a dash-pot.

It is easy to ascertain the tension of the belt. By hooking up the lever frame and pulley carrying the slack belt and taking off the link, the tension of the tight side is shown on the scale beam.

It has been stated that the fulcrums of the lever frames are distant from the axis of the pulleys . . . 4·39 inches,
and that the effective radius of the pulleys, as determined by experiment, was . . . 4·387256

Showing a displacement of the fulcrums of . ·002744 inches.

This displacement as a cause of error will only act upon the frictions of the two idler pulleys and in the same sense, that is to say, upon the sum of the frictions. Assuming this sum to be 10 lbs. the resulting error on the scale beam would be

$$\frac{6 \times \cdot 002744}{8 \cdot 78} \text{ lbs.} = \cdot 00187 \text{ lbs. or about 13 grains too much.}$$

The experiments for determining the effective radius of the pulleys show some interesting results.

To determine where to place the fulcrum knife-edges on the lever frames, one of the pulleys was fastened in a frame arranged as a lever of the first order, with a knife-edge fulcrum in the axis of the pulley. A piece of belt was attached to the frame, and passing over the pulley, sustained a tray for weights. At the other end of the frame, and at a given distance from the axis, was a knife-edge, from which was suspended another tray. From 50 to 500 pounds were put in the first tray and balancing weights in the second. Then, having two known

weights and one known distance, the other distance was determined in each case with the following results:

Let W be the weight on belt at a distance, l, from fulcrum;
w the weight on frame at a distance, L, from fulcrum;
then $l = \frac{w\,L}{W}$, the distance required.

Weight on the Belt.	Effective Radius. Hair Side next Pulley.	Effective Radius. Flesh Side next Pulley.
50 lbs.	4·4666	4·4021
100 "	4·4666	4 4010
150 "	4·4854	4.4102
200 "	4·4727	4·4072
250 "	4·4795	4·4110
300 "	4·4737	4·4182
350 "	4·4850	4·4171
400 "	4·4747	4·4102
450 "	4·4720	4·4075
500 "	4·4827	4·4118
Average, ...	4·47589	4·40963
Mean radius of pulley,	4·30375	4·30375
Gain, ...	·17214	·10588

The above table, which is believed to be comparatively correct, shows that the increased tension of the belt (within the limits of elasticity) does not influence the effective radius of the pulley.

After the knife-edges were placed, and the whole tested by suspended weights, it was found that the fulcrums were too far out, and they were all readjusted. After adjustment, the effective radius of the pulley was found to be

	With Flesh Side next Pulley.	Hair Side next Pulley.
	4·387	4·473
Mean radius, . .	4·304	4·304
Gain, ...	·083	·169

To determine the size of the middle pulley, to measure 3·3 feet per revolution, a frame was made to carry two revolving pulleys on parallel shafts, and the belt of the dynanometer was stretched over them. The length of the middle of the belt was measured by bringing all parts of it successively to the straight stretch. Then about a mile of belt

was run over the pulleys. The revolutions of the belt and those of the pulleys were counted and the length of belt per each revolution calculated, with the following results:

$$\frac{\text{No. of revolutions of belt} \times \text{length of belt}}{\text{No. of revolutions of pulley}} = \text{length of belt per revolution of pulley.}$$

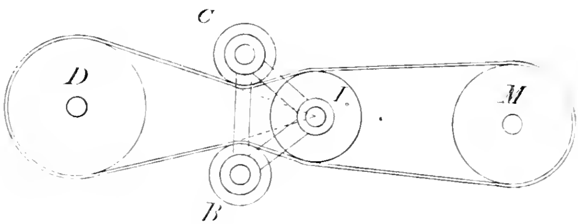
Mean Circumference of Pulley.	Length of Belt per Revolution of Pulley.					
	Flesh Side next to Pulley.			Hair Side next to Pulley.		
	Length of Belt.	Gain. In Circum.	Gain. In Radius.	Length of Belt.	Gain. In Circum.	Gain. In Radius.
44 in. (flat)	44·609	·609	·097	44·778	·778	·124
75in.(high)	75·473	·473	·075	75·845	·845	·134

The middle pulley was made from these data, and was found too large, and was reduced four times and tried, with the following results:

Mean Circumference of Pulley.	Length of Belt per Revolution of Pulley.					
	Flesh Side next to Pulley.			Hair Side next to Pulley.		
	Length of Belt.	Gain In Circum.	Gain In Radius.	Length of Belt.	Gain. In Circum.	Gain. In Radius.
38·805	....	....	....	39·792	·987	·157
38·672	....	....	....	39·665	·993	·158
38·641	39·28	·639	·102	39·659	1·018	·162
38·594	....	....	....	39·595	1·001	·159

The last measurement was made with extreme care, and indicates a delivery of belt per revolution of pulley of ·005 inch *less* than the 3·3 feet desired. The tension on the belts was 190 pounds.

The principle of this dynamometer may be usefully applied to test the power conveyed by a belt running from a driving to a driven pulley in position. The apparatus would be somewhat similar in appearance to the transmission dynamometer described by Professor Thompson in the JOURNAL OF THE FRANKLIN INSTITUTE for February, 1881.



D is the driving pulley and *M* the driven pulley. The pulleys *I*, *C* and *B* preserve their relative position, being all upon one frame, which has liberty to revolve around the axis of *I*, held stationary. The belts leading to and from *D* have no influence to revolve the frame so long as they point through this axis. The belts leading to and from *M* will always tend to revolve it with a moment due to the difference of their tensions acting upon the effective radius of *I*. This difference can be weighed.

This arrangement has these advantages over the form described by Professor Thompson: (1) The pulley *I* need not equal either *D* or *M*; (2) The desired position of the belts leading from *D* towards the centre of *I* can be easily determined by a line or straight edge; (3) The result obtained would not be tainted with the friction of either pulley.

The dynamometer has been made without charge to the Institute, the Isaac P. Morris Machine Co. supplying the pulleys, shafts, bearings and cast-iron frames, and Messrs. Fairbanks & Co. all the scale work —both free.

THE ISOCHRONAL WORTHINGTON PUMPING ENGINE.

By J. K. Maxwell.

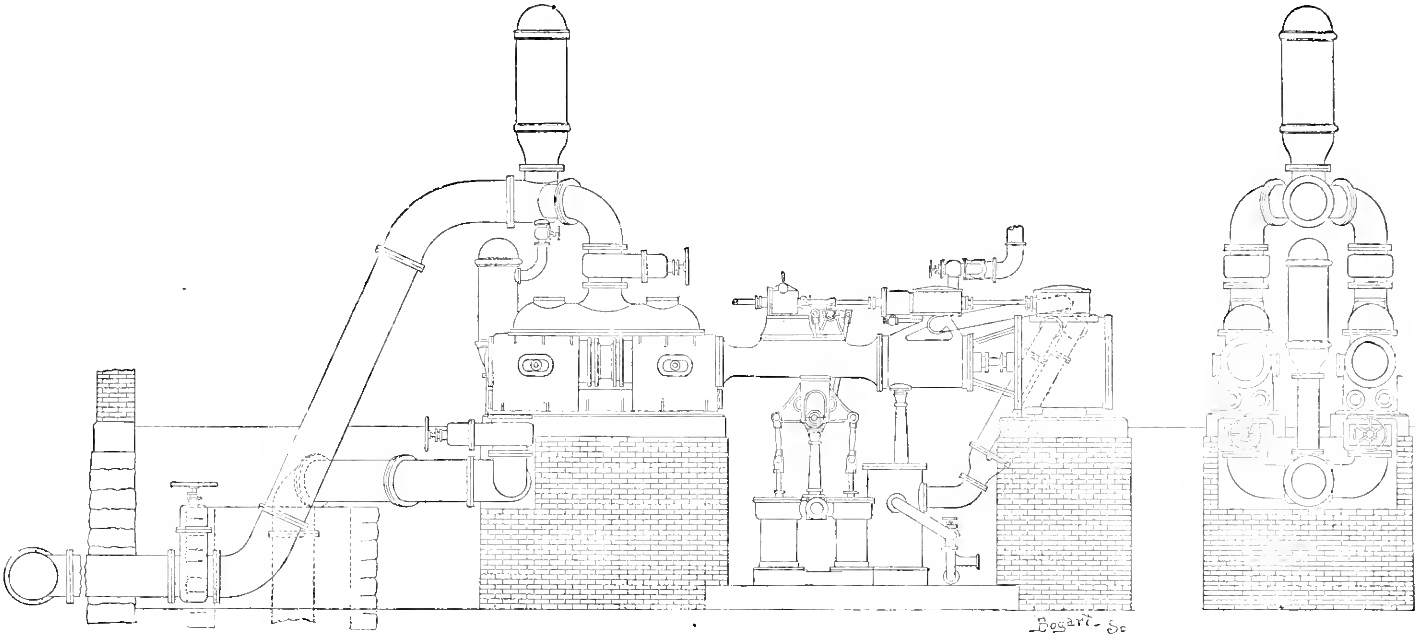
The steam pump is of recent origin, and has just now, by the expiration of the principal patents covering its essential parts, become an article of commerce, in the manufacture and sale of which the public may enter without let or hindrance. As the first steam engines were used for pumping, it is necessary to explain the difference between those and the "steam pump," which can be best understood by stating that the valves of early steam engines used for pumping were operated by bob weights, or springs, lifted or compressed as the engine approached the end of its stroke, and released at the proper time to reverse the steam valves.

The steam pump of the present day is provided with an auxiliary valve-moving engine, the valve of this auxiliary engine being moved by the main engine, and the valve of the main engine moved by the auxiliary engine without the assistance of the momentum of the main engine, the falling of weights, the compression of springs, or releasing of latches of any kind; all its motions being produced by steam direct from the boiler.

Some manufacturers use tappets, so arranged that at rapid speeds the momentum of the main piston assists in moving the main valve, while at slow speeds the auxiliary engine alone performs that office.

There is no record as to the origin of the idea of using one engine to move the valve of another. It was probably thought of soon after engines were made to move their own valves. The first record we have of such an arrangement was in a patent issued in England, to Dixon, in 1837, in which he mentioned two, three or four engines as being so placed that the valve of each could be operated by its neighbor. About 1830 Mr. Penn used a small pump piston and steam piston on the same rod, the valves of the engine being operated by a spring and latch. But little more was done in that direction until Worthington took up the subject, and after considerable labor produced what was called the "Baker & Worthington Jumper," which consisted of a steam piston and pump plunger on opposite ends of the same rod, and a tappet arm projecting from the middle upward, to engage with collars on the valve rod of the engine. The pump plunger worked through a central collar, and when it came near the end of

THE ISOCHRONAL WORTHINGTON PUMPING ENGINE.



Vertical Section of Duplex or Separate-acting Compound Condensing Engine.

the stroke it passed out of the collar suddenly, equalizing the pressure on each end of the pump. So the main piston would jump forward enough to reverse the main valve.

In such a machine it was necessary to establish a resisting pressure in the pump before it could become self-operative. It was useful in its day, but was violent in action, suited only for moderate pressures and medium sizes. It was the principal steam pump in use until 1855, when C. A. Wilson, of Cincinnati, Ohio, and Hubbard & Conant, of New York, invented, and the latter took out a patent for, the first successful steam pump, with its valve operated by steam alone, and provided with cushion ports to prevent the valve-moving piston from striking the ends of its cylinder, which, though a small addition to what was already known, rendered the steam pump a comparatively safe and nearly noiseless machine. This was the first great step toward popularizing the modern steam pump. From 1855, for fourteen years, a great many patents were issued, out of which ten or twelve machines became the basis for considerable manufacturing establishments, and are still sold in the market.

In nearly all, the tappet arm of the Worthington was combined with the valve-moving device of Hubbard & Conant, so that if the latter failed the former would come to the rescue and carry the valve over the ports. A. S. Cameron produced the first successful steam pump without the tappet arm, using the main piston to push open small exhaust valves at the end of each stroke to reverse the main slide valve. In 1866 Cope & Maxwell patented the first successful steam pump operating its steam valve without tappets of any kind. It would work without noise at any speed. There were but two moving parts in it, namely, the main piston and the steam valve. Being without tappets and noiseless, the speed of the engine was limited only by the time required to seat the pump valves, so that very small machines were frequently forced to do more work than they should, and the pump valves were rapidly destroyed. In this type of machine rapidity of action reached its maximum.

About 1859 Worthington's "Jumper" had convinced him that rapid motion in reversing a steam pump was very destructive of its parts, so he doubled the machine and made one engine move the valve of the other, allowing one to rest at the end while the other is making the principal part of its stroke, which, though it seems a small step forward, yet in its practical appli-

cation its effect is almost marvelous. As an artificial means of producing an even flow of water through pipes it has no equal; its effect is superior to any number of pistons driven by cranks arranged on a rotating disk. It is commonly called the Duplex Engine, and is extensively used for waterworks and other heavy pumping. By an improvement adopted by Allison, and subsequently added to by Cope & Maxwell, the same quiet action is obtained in the single pumping engine. A piston attached to the main slide valve, working in a cylinder filled with fluid, with a stop cock in the channel leading from one end to the other, causes the slide valve to move slowly across its ports. The slide valve being provided with the proper lap, produces a pause at the end of the stroke, preventing a sudden reversal, giving quiet action. By arranging the water cushion cylinder on a lever operated by the main engine, and moving in a direction opposite to that of the main slide valve, which is forced along by the auxiliary engine with constant energy, and the resistance being increased through the cushion cylinder by the velocity of the main piston, the main slide valve opens until the main piston acquires sufficient velocity for the two forces to neutralize each other. Then it remains stationary while the piston velocity is constant. If the piston attempts to move quicker it will close the main valve, if slower it will open wider. It is a speed governor, controlling all parts of each stroke, independent of the load on the main engine. It is called the Isochronal Engine, as its piston moves through equal spaces in equal times. By combining the double engine of Worthington with the Isochronal feature of Cope & Maxwell the greatest safety and the most perfect action thus far attained in the direct-acting engine is secured. From the above-mentioned peculiarities it is named the "Isochronal Worthington Pumping Engine."

These engines are of the direct-acting, compound-condensing type, and are fitted with steam-moved valves, controlled by Cope & Maxwell's patent regulator or governor, whereby each machine is accurately controlled under any conditions of service, being in fact an ever watchful and never tiring engineer. The engines are combined and arranged so that each may be run singly if desired; or, in a moment's time they may be changed to work as duplex machines; engine No. 1 controlling its own main slide-valves through its governor, moves the auxiliary slide-valve of engine No. 2, to admit steam to move its main slide-valve; while engine No. 2 controls its own main slide-valves through

its governor, and moves the auxiliary slide-valve of engine No. 1 to admit steam to move its main slide-valve, thus keeping up a continuous plunger action and flow of water from the pumps. Each engine has an independent condenser and two air-pumps, the latter being operated from the rock shaft that gives motion to the governor or regulator cylinder.

The pumps are of the plunger variety, with packing-boxes in the middle, between the valve chambers, which admits of the packing being tightened up while the pumps are in motion. The pump-valves are easily accessible for inspection by the removal of a single cap at each end of the pump chambers. Ample air and vacuum vessels are provided, as are also shut-off valves for the suction and discharge pipes of each pump.

EXPLOSIVE AND DANGEROUS DUSTS.

By Prof. T. W. Tobin, C.E., Ph.D.,
Of the Polytechnic Society, Kentucky

[An address delivered before "The Fire Underwriters' Association of the Northwest," at the Thirteenth Regular Meeting, held at the Grand Pacific Hotel, Chicago, September 6, 1882.]

During the month of May last I was honored with an invitation to address the Kentucky Millers' Association on "Flour Explosions." Being a subject in which I had for many years been interested, I cheerfully undertook the preparation of a lecture, with illustrations. The experiments, although not new, for chemists well know the combustible nature of organic dust in a finely divided condition, yet so impressed my audience that I was more than repaid, on my part, in their interest and applause for the small amount of labor expended. In preparing that lecture there appeared to me certain conditions governing the combustible state of flour which hitherto had been passed by in investigating the appalling catastrophes that from time to time befall our national industries, in the form of mill fires and explosions. Many of my suggestions, the outgrowth of subsequent experiments, have been received with favor; and my theories, if such I may presume to term them, have had the endorsement of practical men before whom they have found their way. The desire to prosecute the

truth, which is implanted in every scientific mind, has led me further, and I am here to report progress and court your criticism.

Dust Under the Microscope.—Let us together then retrace the narrative of these researches. I will first call into requisition that wonderful instrument that science plunges into the mysterious and opens out its inner secrets to the light of day—the microscope. As it would be difficult to show you individually the objects that I shall employ as illustrations, I made careful drawings and photographs of them, and by means of a powerful oxyhydrogen light will project magnified images of these upon the disk now before you. (*The lecture room was here darkened and the subsequent microscopic illustrations shown on a screen, magnified to many million times the size of their originals.*)

1. I take first some ordinary flour, commonly known as "*Graham meal*," and we find that it consists of quite a miscellaneous gathering of various bodies. There are present: (1), the skins of the wheat-berry; (2), the hairs or "beard;" (3), cells of gluten, a waxlike substance, being the most nutritious portion of the grain; and lastly, (4), the starch in various sized granules. This body forms the bulk of ordinary flour and flour-dust. Now, in order to understand intelligently the natural placement of these parts of the wheat grain, I will bring magnified images of that body.

2. This shows: (1), the beard; (2), the skins, three in number, that enclose the internal starch or gluten; (3), at the bottom there will be noticed the germ, and contiguous with it the crease. Now, the first operation of the miller who has recourse to the newer processes of reduction, is to clean by brushing or agitation, the whole surface of the grain for subsequent operations, and 2d, to break open this crease and get rid of the germ and incidental impurities that are usually there. In so doing a small amount of flour is made, but being charged with impurities, is blown into the dust-room. There are then two classes of dust: 1st, wheat dust, obtained from cleaning the surface of the grain, and 2d, the refuse flour dust discarded, because being mixed with germ and other foreign matter. Although in my investigations I found two separate channels and outlets, the character and condition of both classes of dust therein were almost identical in physical properties.

3. This will show by a section of the grain the disposition of the parts already described.

4. Pure starch granules, as found in "arrowroot." This may be taken as the typical element in flour dust. We mark the compact spheroidal form of the granule. At a temperature of 140°F. in water it swells, bursts and is converted into the well-known pasty mass used in the arts. In common with most organic matter, starch is combustible, and contains normally about 18 per cent. of water.*

This amount varies, and exposed to a dry atmosphere, may be considerably reduced. I take it as a rational deduction that the most rapid combustion of flour, attended with explosive violence, would occur when freed from moisture. The individual granules burst simultaneously, and the disturbance thus produced bringing new supplies of oxygen, would instantly determine the rapid consumption by fire of the entire mass. This fact will be discussed further on.

5. Immediately following the starch granules we have a quantity of dust obtained from the club moss, called "lycopodium." It is the seed or spore of that plant. Notice the near resemblance in size and structure to the starch granule; but it differs in one respect in being of an oily nature, which (as our experiments will presently convince us), renders it very inflammable.

6. This is highly bolted flour, and as the microscope shows, freed from the husk, the beard, and even the gluten of the wheat, leaving nearly pure starch. We observe that there are three distinct qualities of the granule; (1), the giant; (2), the medium, and (3), the farina, or starch powder.

7. This view will give a fair idea of what change takes place in starch on submitting it to a heat of over 140°; in other words, it is cooked flour. The granules have all disappeared, and in their place are irregular masses of amorphous "dough" or "paste."

8. Some dust collected from the "wheat dust room" shows starch, husk, fractured gluten cells, the beard, and other impurities; it also contains, generally, "fungi," or "smut." The dry and oily nature of this dust renders it more inflammable than starch.

9. Wood abrasions from an axe-handle factory, showing the fibrous and cellular texture of the minute particles of dust. This material is inflammable owing to its extreme dryness.

COMBUSTION.—I will now as briefly as possible lay down the principles that are generally acknowledged by chemists as underlying the phenomena of combustion in organic bodies and apply them to the

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* Miller's Elements of Chemistry.

special instances under consideration. The substances which we will deal with to-night consist of three elements; oxygen, hydrogen and carbon. Although in variable quantities the oxygen and hydrogen are always in the ratio of water, *i. e.*, eight parts by weight of the former to every one part of the latter; heat is capable of determining their union and water is the result. Carbon or charcoal is thus left, and being incapable of existing in any but a solid condition, soon stifles further combustion. If, however, oxygen be added, either from the air or as a gas, perfect consumption of the body takes place. We know that a piece of wood, if an insufficient supply of air is present, can only become charred by the most intense heat known. This is the first principle that I will now endeavor to illustrate.

Experimental Demonstration.—Here is some hydrogen in a tube; it is very much the same as that burning from the lamps in the room. I plunge a lighted taper into it, and the taper is incapable of burning for lack of oxygen or air. Hydrogen, although a highly combustible body, will prevent combustion, and even suffocate this burning taper. I now add some air, neither in itself explosive nor combustible, and then heating the mixture, I get a deafening report. Beyond all question, I have generated an explosive body.

Then I will take some flour, and perhaps I should tell you that, like the hydrogen when free from free oxygen or air, it is incombustible. Flour thrown on the glowing furnace will retard and even, if sufficient in quantity, extinguish the fierce fire. Like hydrogen alone, it is a non-supporter of combustion. Observe, I plunge a burning taper in this measure of flour, and, as you would predict, the taper goes out. Here is a substance, chlorate of potash, which is very rich in oxygen, and I cannot alone make it burn, as you may see. Two harmless bodies I mix; the essentials of combustion are supplied and brilliant fire is the result. Oxygen gas, always present in the air, an exceedingly active and corrosive body, is then the one thing needed to render these inert bodies combustible, and even explosive.

Moisture.—Water, in all its forms, is opposed to combustion, and its presence modifies the rapidity with which the consumption takes place. It is, I think, hardly necessary to illustrate this as a general principle, although in the sequel we shall find in it an element of great importance.

Now, it is by these simple principles that combustion in its varied phases, from the slow decomposition and decay of the green vegetable

to the explosion of the modern flour mill, is governed. By the modification of them I think I can show you some interesting results.

WOOD DUST.—Here is some dust from an axe-factory. It was obtained and has been preserved in a dry state. By means of a simple piece of apparatus I cause it to be blown about and thoroughly mixed with air. A flame is near it, rapid combustion takes place, and a column of fire of intense heat leaps up in the air, six or seven feet high.

FLOUR DUST.—This sack contains ordinary flour. Previous to the lecture some of it was placed in a drying oven and submitted to gentle heat. By this time much of the moisture usually contained in flour has been expelled; one condition has been filled to make the substance combustible. I next comply with the other and mix it with air. See the result! Mark the violence attending the combustion.

You may seem astonished, and ask whether this is flour alone. Yes; from the same sack I use some more: this time not with the same and result, for it is damp and the air cannot mix sufficiently to render it even inflammable.

Then we arrive at a very important conclusion. The violence of combustion is the inverse of the moisture of the dust experimented upon.

OTHER DUST.—We will now put the testimony received so far to the torture of further investigation. I have some lycopodium. You remember its near resemblance to flour dust under the microscope. It is not necessary to dry this as we did the flour, for it is protected by an oily waterproof coat and moisture cannot enter it, but it requires air, for I plunge a lighted taper into its midst, and, as in other instances, neither will the powder burn nor will the taper. I urge some of it through the heated flame with this unexpected result: an all-devouring, an explosive column of fire.

EXPLOSION.—The results obtained so far convince us that dust is inflammable in degree according to its dryness. No actual explosion has yet been obtained in our experiments. Perhaps it will be well to define the term explosion since there has been objection raised to its use in connection with flour combustion by some writers whose opinion is worthy of respect. It almost seems ridiculous to imagine anyone looking at the disaster at Minneapolis, could so pervert the English language as to say that no "flour explosion" took place. Our dictionaries give us the definition of the word "to drive or burst out with a loud report or violence." Hitherto we have not then complied with

this definition and therefore had no explosion. Let us see if it is possible to obtain explosion, and by what means. When dry organic dust is heated to the point of ignition, the oxygen and hydrogen first combine to form water. Intense heat is thereby generated, and this heat acts in two ways: first, to char and finally convert the carbon into carbon dioxide gas; and, secondly, to expand the surrounding air. The gas and the heated air occupy considerably more space than in their first state, and the more rapidly these results are achieved the more nearly will the act approach the violence of explosion. The air then plays as important a part as the dust, and should the air space be confined, but insufficient to restrain its force of expansion, explosion in the full sense of the term takes place.

EXPLOSION, INTENSITY OF COMBUSTION.—We can trace the various degrees of combustion in the many mill and factory fires that have been placed on record. Notably amongst them I will call your attention to two—the terrible disaster of Minneapolis, which occurred May 2, 1878, and the Hecker mill fire in New York, July 31, 1882. In the former we may reasonably infer that the air was dry and the dust pretty generally diffused throughout its entire extent, owing to the long continued and busy period the mill had been taxed with work. The wheat of that year, we are told, was hard and dry, and at the time of the explosion, 7.20 P. M., the air was chilly and the windows and openings generally closed. Here are conditions for explosion. In the latter I will take the testimony of the superintendent, Mr. J. V. Hecker, as recently given before the fire marshal of New York. He says: "The fire originated in the 'smutter' on the seventh floor. 'Smutters' are considered the most dangerous parts of the machinery of a mill, on account of the friction which may be produced by any foreign substance getting in and striking fire between the revolving cylinder and the case surrounding it. These cylinders were of stone and the cases of chilled iron. The smutters make from 250 to 300 revolutions per minute. The dust is sucked from under the smutters and forced by a fan into the (wheat) dust room through a spout about ten inches square. I think the fire was caused by a spark struck by friction in the smutters, igniting the dust and passing through the spout into the dust room and igniting the dust therein." That an explosion did not then occur, as in many other instances was, I take it, owing to the fact that while the air in the mill was charged with fine dust the dryness was sufficient to cause the flames to spread with

lightning-like rapidity through the entire building, making the 500 workmen run for their lives. There was insufficient moisture to allow the dust to burn with the violence characteristic of an explosion. From the meteorological record of that day I find the barometer stood at 30·42, temperature, 82°F., and there was 82 per cent. moisture in the air, with cloudy sky. Thirty per cent. of humidity that day, in all probability, saved the nation from a disaster far more terrible than happened in Minneapolis, or since the history of milling has been recorded.

Many other illustrations might be taken which would find an intermediate place in the degrees of intensity of combustion. You will call to mind the candy-works explosion in the same city some years ago that was an explosion of starch. The Ehret Brewery in August, 1881, experienced an explosion from the barley used in malting. Barley, in common with wheat and other cereals, consists principally of starch, and no difficulty is experienced in accounting for that phenomenon. The Pullman Car Works, at Detroit, 1880, had an explosien of dust in the spout used for conveying shavings from various portions of the factory to a place near the furnace. This spout is the counterpart of the dust room of the flour mill.

Conditions of Explosion.—We will now proceed with our experiments and see if we can cause those substances which hitherto have shown themselves as highly combustible, to become explosive. We will confine the air space and see the result. For that purpose I have before you a simple piece of apparatus which, for a better name, we will call a dust or flour gun. It consists of a hollow shaft about seven feet high. At the top is a hopper, which by means of a paper cover I can close; at the bottom is a gas pipe to which is attached a Bunsen burner. By means of a trigger arranged near the top I can cause a fine shower of dust to descend and fill the shaft. When the first portion of it reaches the flame and the shaft is filled with dust, ignition takes place and the entire column burns. It is necessary that there should be a plentiful supply of air. This is provided for in numerous perforations about the walls of the machine. If the dust is now dry we have all the conditions for explosive combustion. Let us proceed:

I place some lycopodium and turn the trigger. The top is blown off and takes fire, so intense is the heat. Here is some wheat dust from the dust shaft of a flour mill. The result is much the same,

only less in degree, and yet sufficiently illustrates the principles we have discussed.

The Wet Bulb Hygrometer.—Before proceeding further in our subject it is necessary that we should understand the construction and use of an instrument that will play an important part in the subsequent line of thought I purpose now leading you. It is known by the modest title of "Wet Bulb Hygrometer," and its mission is easily related.

Its indications tell us that the atmosphere about us on the clearest and brightest day or night contains a large amount of water dissolved in it; that this watery vapor or gas is very transient in its nature, but that very seldom is the air fully charged, and never is moisture entirely absent. When the air has as much water as it can possibly hold we call it saturated, and in that condition we say it has one hundred per cent. of humidity. Cold air requires less moisture to saturate it than warm air, hence elevation of temperature means increase of the saturating point.

It tells us that there is a constant variation going on—sometimes at short intervals, and at others in long periods; and it further shows, as we are ready to anticipate, that there is a constant change in the capacity of the air and amount of moisture in it during the twenty-four hours of each day. As I take it, this atmospheric property plays an important part in our investigation of dust combustion.

In various localities the average capacity of the air varies considerably. "In the North American Continent," says Ganot in his admirable text-book on physics, "where the southwest winds blow over large tracts of land, the relative moisture is less than in Europe; evaporation is here far more rapid; clothes dry quickly, bread soon becomes hard; newly built houses can be at once inhabited; European pianos soon give way here, while American ones are very durable on the other side of the Atlantic. As regards the animal economy the liquids evaporate more rapidly, by which the circulation and the assimilation is accelerated and the whole character is more nervous. In some parts of East Africa, on the other hand, the air is so charged with humidity that paper becomes soft and sloppy from the loss of its glaze, and gunpowder, if not hermetically sealed, refuses to ignite." As a suggestive thought incidentally to these statements—are not the greater number of mill explosions in districts over which a dry atmosphere is known generally to exist? By the indications of this instru-

ment we find regular changes during the day, there being maxima about 8 A.M. and 8 P.M., and minima about 3 A.M. and 3 P.M. The Signal Service record (Louisville) for a few days will suffice to show this fact:

	6.25 A.M.	10.25 A.M.	2.25 P.M.	6.25 P.M.	10.25 P.M.
Aug. 1,	90	79	59	72	88
Aug. 2,	82	62	51	61	85
Aug. 3,	90	67	57	90	93

CONSTRUCTION.—The instrument in construction is simple, consisting of two delicate thermometers, one of which is kept saturated by a reservoir of water. As the air loses or gains in capacity to dissolve moisture evaporation takes place from the wet instrument. Proportionate to the capacity of the air to contain water will be the degree of evaporation, and the extent of evaporation is indicated by the lowering of temperature. Thus, by a very easily constructed table, showing the difference of temperature readings of the two thermometers, a pretty accurate estimate may be made of the amount of water necessary to produce saturation and the amount already contained therein. The instrument may be easily constructed or purchased for a few dollars at any first-class optician's. It should, however, be accurately adjusted and the scales properly constructed. I will not occupy your time in explaining further how the readings are made, as that information may be obtained from any good text-book on meteorology, but will at once proceed to detail records arrived at by its aid in my subsequent description.

MILL FIRES.—The principles I have heretofore laid down, simple as they may appear, I felt convinced underlaid many of the fires and terrible explosions so disastrous to flour mills, and to their ignorance I conceived might be attributed at least some of the most awful catastrophes chronicled in our industries. Every year, to his sorrow, the mill-owner finds his risk of destruction of property and life growing greater, and I believe to-day there are insurance companies that would as soon grant a policy upon a gunpowder magazine or dynamite factory as to the proprietor of a flour mill. I determined to submit these principles to a rigid test. Accordingly, with hygrometer and note book in hand, and the valuable co-operation of Mr. Chas. Ballard, a

practical miller, I penetrated every crevice and chamber, from basement to roof, of one of the best-ordered mills in the country.*

I will not occupy your time in describing the various parts of an ordinary flour mill, but make use of the technical terms applied to the various localities. Suffice it to say that the mill in queston has every modern improvement in milling machinery, is substantially constructed of brick, is run by steam power and well ventilated from all sides. The grain is received in the basement; the first floor is devoted to gradual reduction mills, and the second and third floors to bolting machinery and purifiers of the most approved description. It has a capacity of 180 barrels per day.

Mathematics cannot err; mark, now, the extraordinary records:

Record of Temperature and Humidity of the Atmosphere at the Flour Mill of Messrs. Jones, Ballard & Ballard, Louisville, Ky., August, 1882.

Date.		External.		Internal Humidity.			Weather.
Day.	Hour.	Temperature.	Humidity.	Grinding Floor.	Bolting Floor.	Dust Shaft.	
Aug. 10....	11 A.M.	70°	52 P. C.	67 P. C.	54 P. C.	....	Clear.
Aug. 11...	12 M.	80°	51 "	62 "	65 "	....	Fair.
Aug. 12...	3 P.M.	82°	45 "	60 "	53 "	....	Fair.
Aug. 14..	3 "	89°	53 "	54 "	53 "	43 P. C.	Fair.
Aug. 15...	1 "	81°	87 "	83 "	83 "	60 "	Rain.
Aug 16...	1 "	82°	83 "	87 "	87 "	63 "	Rain.
Aug. 17...	3 "	79°	57 "	64 "	64 "	53 "	Clear.
Aug. 18...	3 "	83°	48 "	52 "	52 "	38 "	Clear.
Aug. 19...	2 "	78°	50 "	55 "	58 "	41 "	Fair.

The first unexpected result we notice in these records is that the atmosphere in both grinding and bolting rooms is moister than the air outside. On closer examination I soon discovered the cause of this.

* This mill is situated in Louisville, Ky., and owned by Messrs. Jones, Ballard & Ballard.

Each set of rollers used in reducing the grain, 22 in all, was heated, owing to the friction and resistance in crushing. By the heat thus generated the normal moisture of the wheat was continuously being evaporated, and escaped into the mill; the spouts near the rollers were bedewed with moisture and the flour doughed. Notwithstanding that the windows on all sides were open, and the ventilation as thorough as possible, the entire atmosphere of the mill was thus kept in a moist condition.

After carefully examining the purifiers, bolting chambers, wheat cleaners and other machinery for the dangerous element of dry air, I came lastly to the dust shafts. As I have already stated, in this mill there are two of these—one used for collecting the dust from the wheat cleaning, which is carried to the basement and there collected in a dust room; the other carries off the light refuse flour dust made in the first reduction of the grain. In making observations I found the amount of moisture in both these shafts, and the various parts of each one, differ so slightly that I did not deem it desirable to note the variation.

THE DUST SHAFT.—Could science speak plainer to us than in these facts? Recall the many mill fires and explosions that periodically visit us, and does not each narrative begin with the now easily interpreted incident, that destruction commenced at the dust shaft or in its vicinity? Here, month after month, streams of dry air, drier than the hot summer breezes, are urged with the velocity of a storm, depriving the wood and other combustible matter of its moisture, converting all that will burn into tinder-like fuel, dry air separating and buoying up the particles of drier dust until the fatal spark occurs and combustion ensues, with the explosive violence, alas! too well known now to need description.

I do not hold that mills are blown up by the dust alone in the shafts, but I do believe that the fires generally originate there, and the local explosion caused thereby is often sufficient to fill the entire atmosphere of a mill with lodged and loose dust. A second charge is thus prepared for combustion, and the grand explosion occurs.

Dust shafts are then danger centres. Can there be any longer doubt in your minds? Is it necessary for me to suggest that they should be well protected and solidly constructed? Dry air in a mill, I am inclined to think, is little less dangerous than coal gas escaping in the air. Why make these shafts of light match boarding? Will you longer, in face of these deductions, use gauze and canvas doors com-

municating with them and your mills? As I stood one day near by one of these doors my hygrometer showed the dangerous enemy stealing into the dust-charged atmosphere of the mill.

Having accepted the fact, which I take for granted is now settled in your minds, that the dust spouts and flour shafts are drier than the surrounding atmosphere, let us see if science can explain why this should be so. Nearly all dusts are well known to chemists to be hygroscopic in their character. Flour especially will divest moisture from the air. But we have seen also that in the process of grinding, by the heat generated in friction, a large amount of the normal moisture of the grain is driven off and the subsequent heated flour must necessarily be abnormally deficient in water. The percentage of moisture in the dust shafts would be, of course, governed by the humidity of the external atmosphere, as we find it shown in the table set forth.

The Barometer.—There is another interesting relation between the dust and the atmosphere as its medium, which is at least worthy of a passing remark. Do you know that dust is sometimes lighter than at other times? More correctly, the atmosphere, in its variable density, causes the light particles of floating matter to become more or less buoyant. Let me illustrate the statement by a familiar incident: Have you not noticed at some times, generally on a dry day, how the smoke rising from the chimney will rise and be buoyed up in an almost vertical direction—how on those days the very dust in the roads hangs about and refuses to settle? The barometer on these occasions will be high, showing that the air is dense. Another day the air will be charged with moisture; the smoke hangs about the ground, no dust in the air now, for the air is too light to buoy it up; the barometer is low and rain is probable. Is it only reasonable to infer that during a high barometer the lighter particles of flour are reluctant to settle, and, floating in the air, add to the many dangers of a flour mill? I make this brief allusion to a probable cause conducive to fire and explosion. Time will permit me to do no more.

Deductions.—Gentlemen, the accurate diagnosis of disease points to a line of remedy. Have we not enough information on the cause of dust explosion to suggest a mode of remedy? It may be that we have not yet gone to the bottom of the mysteries involved, but we have, I think, indications enough to adopt a line of treatment.

Let me, as I have presumed so far, in the interest of science suggest:

1. That dust rooms are dangerous centres, and should be built, if possible, of brick, as you would build a smoke stack, and all communicating shafts and doors be of sheet metal.

2. That, as in the long period of drought in summer nature moistens the dry forest with rain and dew, so our parching winds, constantly blown through shoots, shafts and dust rooms, should be daily, if practicable, charged with vapor or steam.

3. Keep the mill free from superfluous dust and flour.

4. As dry air is the miller's enemy, let him learn to use the hygrometer, and on its indications adopt methods, as he may think best, to drive it from the many lurking places in his mill.

5. In dry weather, when the air is dense and thick with floating particles, let him not overwork or strain the capacity of production. Overtaxing work has often preceded disaster.

6. Never use open lights in the mill if it is possible to avoid them, and get as much ventilation as possible.

CONCLUSION.—Before concluding the subject I have attempted to lay before you, the cause of events makes it necessary to add one more record. After I had formed the line of thought and made observations at Messrs. Ballard & Co.'s mill, an incident occurred that riveted my interest, as I think it will yours. After hunting nature to the utmost limits of investigation, I was rewarded beyond measure in an occurrence which took place unexpectedly to all, but unfortunately for my friends in labor, the Messrs. Ballard.

When lecturing before the Millers' Association of Kentucky I made the following remarks: "Could we have had a register of the state of the atmosphere in the unfortunate Washburn mill, Minneapolis, immediately preceding the explosion, I doubt not that it would have shown a marked absence of humidity." Science has permitted me to realize this, for on Aug. 22d my closing record at the mill reads:

Date.	Hour.	External.		Interior.	Weather.
		Temperature.	Humidity.		
Aug. 22.	11 A.M.	82°	60	Wheat dust shaft and adjoining bin on bolting floor now in flames. Fire confined to upper portion of shaft, but fierce and destructive.	Fair.

What originated the fire I pass uncommented upon. The fact that the dust shaft burned with rapidity, and that the entire mill was but a wreck from either the flames or explosion, I leave for your thoughtful consideration. On the spot where I had made my observation, in the wheat dust room, the last time I visited the building, there remained only the ruins of property estimated from eight to ten thousand dollars.

ECONOMICAL STEAM POWER.

By William Barnet Le Van.

[A paper read by title at the Stated Meeting of the Franklin Institute, Oct. 18, 1882.]

Up to this point I have spoken of the engine only, and now I propose to investigate boilers and their adjuncts. A few years ago fifty pounds per square inch was thought a high pressure of steam to use in mills, but of late years pressures of seventy-five and one hundred pounds, and even one hundred and twenty pounds per square inch have become common. I predict that the day is not far distant when one hundred and fifty and two hundred pounds per square inch will not be uncommon.

The efficiency of a steam boiler is measured by the number of pounds of water it will evaporate into dry steam by the combustion of one pound of coal, compared with its cost; that is to say, the quantity of steam produced for its first cost and the least total cost for running it.

The thirty years experience of the writer is to the effect that the deficiency of a large number of good boilers in producing steam economically is due solely to their imperfect brick settings, flue connections and improper proportioning of grate surface to heating surface. To make them good, economical steam generators a resetting of their brick work is all that is required.

To illustrate: Some years ago a large manufacturer in this city consulted the writer in regard to the great quantity of coal consumed under his boilers. On making an examination it was found that the chimney and main flue were all right, but about thirty square feet of the most effective heating surface of each boiler, immediately over the fire grate, were rendered practically useless from being enclosed in brick work.

There being five boilers in all, the loss of effective heating surface amounted to about one hundred and fifty square feet of direct radiant heating surface.

The consumption of coal being twenty-five tons per day, this enclosed heating surface over the fire bars was a matter of great importance, as it is well known by experienced boiler engineers that *each square foot* of heating surface, above the fire bars, is equal to *ten square feet* of heat transmitting power in the flues; and these boilers having tubular flues the extent of the loss may be readily seen. I would state that these boilers were designed and built, and also set in brick work, according to the plans and specifications of one of the largest and most successful firms in this city. The owner of the establishment was a gentleman of education and intelligence, and when I brought the matter before him and explained what alterations were necessary in order to reduce the coal consumption, and the reason therefor, and that the only remedy lay in the resetting of the boilers, he was at once satisfied and ordered them reset.

The boilers were altered under my directions and the result was a better quality of steam and a saving of *five tons of coal per day*, at a cost of *five dollars per ton*, or *twenty-five dollars per day*, that is, *twenty per cent.* of the total consumption of coal.

At the Centennial Exhibition the greatest care was taken in the brick settings of the boilers for trial, and the results showed how well the extra outlay was repaid; the lowest evaporation in horizontal tubular boilers being 10,216 *pounds* of water evaporated, at 212 degrees, per pound of combustible.

In the writer's opinion steam boilers, as now constructed, can be very little improved on; but in regard to their brick settings and flue connections there is a large field for improvement, especially in the construction of the *combustion chamber*, which should be so arranged that combustion of the gases started in the furnace may be completed before they escape into the chimney.

Combustion Chamber.

The ordinary combustion chamber is invariably made too small, both in height and width.

The general proportions allowed are so limited as to give it rather the character of a *large* conduit, whose only function should be to allow the combustible gases to *pass through* it, rather than that of *a*

chamber in which a series of consecutive chemical processes are to be conducted. Such furnaces, by their diminished areas, have also this injurious tendency—that they increase the already too great rapidity of the current through them. The defect of insufficient capacity in the chamber of the furnace, *above the fuel,* will be best appreciated when we consider that in it the gases are generated, their constituents separated, each brought into contact with the oxygen of the air, and finally their combustion effected.

The practice of constructing furnace chambers so shallow, and with such inadequate capacity, appears to have arisen from the idea that the nearer the body to be heated was brought to the source of heat the greater would be the quantity received. This is no doubt true when we present a body to be heated in front of a fire. When, however, the approach of the colder body will have the direct effect of interfering with the process of nature (as in gaseous combustion) it must manifestly be injurious. *Absolute contact* with flame should be avoided where the object is to *obtain all the heat* which could be produced by combustion of the entire constituents of the fuel.

Dr. Ure observes: "When a boiler is set over a fire its bottom should not be set too near the grate lest it refrigerate the flame and prevent that vivid combustion of the fuel so essential to the maximum production of heat by its means. The evil influence of leaving too little room *between the grate and the boiler* may be illustrated by a very simple experiment. If a small copper or porcelain capsule containing water be held over the flame of a candle, a little above its apex, the flame will suffer no abatement of brightness or size, but will continue to keep the water briskly boiling. If the capsule be now lowered *into the middle of the flame* this will immediately lose its brightness, becoming dull and smoky, covering the bottom of the capsule with soot, and owing to the imperfect combustion, though the water is now surrounded by the flame, its ebullition will cease."

When, however, the object is merely to raise a body to a high temperature, by local application, as when we heat a bar of iron in a blacksmith fire, or a flame, and without reference to the quantity of heat produced and wasted, indirect contact becomes necessary.

So much, however, has the supposed value of near approach, and even contact, prevailed that we often find the space over the fire grate about twelve inches deep, and behind the bridge wall, frequently but

a few inches deep, so as to bring the flame in contact with the boiler, as shown in Fig. 1.

As a general rule, deduced from practice, it may be stated that the depth between the grate bars and the bottom of the boiler should not be less than twenty inches where the grate is but four feet long, increasing in the same ratio where the length is greater; and secondly, that the depth below the grate bars should not be less than twenty inches, although this depth is not so essential.

The forming of combustion chambers back of the bridge wall, extending down below the grate bar to the level of the ash-pit, is a

Fig. 1.

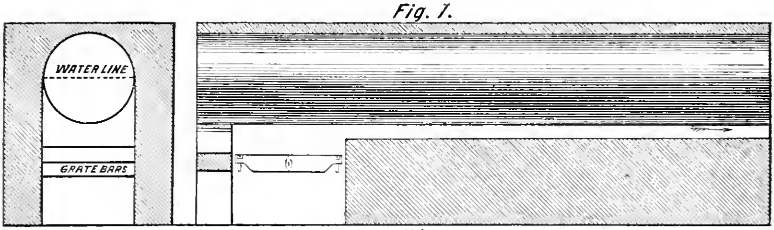
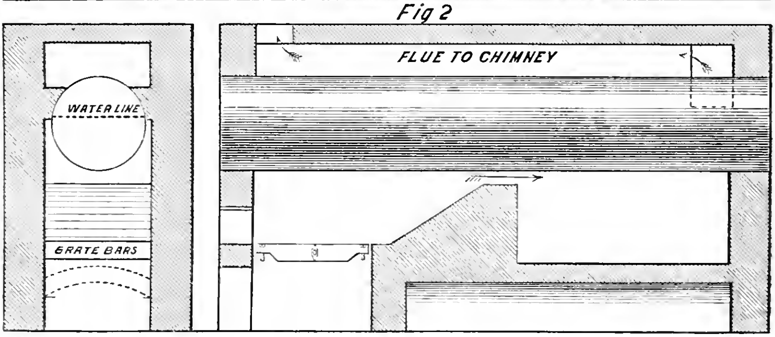


Fig 2



source of great loss of heat, especially if the sub-soil is damp. (The experiments of Professor Tyndall revealed the astounding fact that the power of aqueous vapor, at the pressure of the atmosphere, to absorb heat is six thousand times greater than that of dry air.) Or, in other words, damp air loses heat by radiation in the proportion of seventy to one of dry air, as heat is absorbed by moisture in addition to the radiation of the walls surrounding the chamber.

The writer lately reset a plain cylinder boiler having a chamber open to the ground floor back of the bridge wall. This chamber the writer arched over, about eighteen inches from the bottom, and the

result was a saving in coal of about *ten per cent.* These air chambers are non-radiators. Professor Tyndall's experiments on this subject have clearly demonstrated that *dry air* is absolutely non-radiant.

In another case, four plain cylinder boilers, set on the same plan as that just described and having the grate bars but fourteen inches from the bottom of the boilers, were reset by raising the boilers twenty-four inches above the grate bars and arching over the combustion chambers back of the bridge wall, and also forming a flue along each side of the boilers, of about four inches wide, up to the top of the water line. (See Fig. 2.)

The result was, that while *seven tons* of coal per day was burnt before the resetting, the coal consumption after resetting was reduced to five tons. My latest practice is to form a flue so as to return the products of combustion over the top of the boiler, as also shown in Fig. 2, thereby to a great extent reduce the steam down to nearly dew point.

The ordinary furnace, as generally built, does not allow sufficient space for a complete mixing of the gases, and although the air admitted, due to imperfect fitting of the doors, mixes with the gases, the temperature of the mixture is not high enough for ignition, and the gases pass off unconsumed.

By increasing the distance between the bottom of the boiler and the grate bars and carrying a moderately thick and hot fire, with a rapid draft, and a proper admission of heated air above the grate bars and a thorough mixture of the gases evolved, with the hot air admitted, perfect combustion can be attained.

The admission of air above the bars is on the same principle as the flame from a Bunsen burner. This flame, as every one knows, is almost colorless, and is never used for giving out light; but from the intimate mixture of air and gas, produced before ignition, it is intensely hot. In fact, the radiation of a flame is to a great extent due to heated, unconsumed solids and dense gases, and when, as in Bunsen's burner, a proper amount of *hot* air is supplied to an ordinary coal gas flame, these dense particles are consumed the combustion being complete.

That it is the presence of dense gases which gives luminosity to a flame has been shown by numerous authorities. On increasing the pressure of the gases burnt the luminosity is greatly increased, and candles burn with less light at the top than at the bottom of a moun-

tain. If the ordinary candle be lighted on the top of a high mountain it will be found that the candle loses, by burning, as much of its own weight, in a given time, as if it were burned at sea level. In respect to its luminosity, however, it is the mere shadow of what it is at low altitude, in fact, it burns more like a spirit lamp.

It has been determined, experimentally, that carbon, in burning from the solid condition to carbonic acid, generates 14,500 units of heat, or 100 pounds of water from 67° to the boiling point, or converts 15 pounds of water, at 212°, into steam, or lifts 11,194,000 pounds one foot high, and carbon, in burning to form carbonic oxide, generates 4452 units. That is to say, one pound of carbon, in burning to form carbonic acid, generates heat sufficient to raise 14,500 pounds of water one degree. If, then, it generates 14,500 units of heat in burning to carbonic acid, and only 4452 units of heat in burning to carbonic oxide, it follows that carbonic oxide, containing one pound of carbon, would generate in burning to carbonic acid 10,048 units, so that carbon in burning through its first stage to carbonic oxide gives off only about *thirty per cent.* of that which it gives off in completely burning through both the first and second stages to carbonic acid. (Hydrogen in burning to form water generates 62,000 units of heat.)

We thus see the necessity of admitting a sufficient supply of air to the coal when burning, not allowing any of it to escape in the form of carbonic oxide and thus doing away with the prodigious unnecessary waste, which takes place when carbonic oxide is allowed to burn in or at the top of the chimney instead of in the furnace or combustion chamber.

We often see flame coming out of the top of a chimney, especially those of river steamers; this is chiefly carbonic oxide which is burning, not the flame of the fire below which reaches up to that height. Whenever carbonic oxide is so formed, the coal is being burnt at a great loss, as a great quantity of the heating power is being sent up the chimney.

Dynamical Value of Combustion.

The unit of heat being one pound of water at 39° Fahrenheit raised one degree Fahr. in temperature, and the mechanical equivalent of this heat being 772 foot-pounds, the dynamic value of the combustion of one pound of gaseous hydrogen is

$$62{,}000 \times 772 = 47{,}864{,}000 \text{ foot-pounds.}$$

So that if it were possible to convert the whole of this heat into available power, the combustion of one pound of hydrogen gas per hour would develop a force equal to

$$\frac{46,864,000}{33,000 \times 60} = 24 \text{ horse-power},$$

and as a pound of solid carbon in burning to carbonic acid develops work equal to

$$14,500 \times 772 = 11,194,000 \text{ foot-pounds},$$

the combustion of one pound per hour would, therefore, in a perfect engine, exert a force of

$$\frac{11,194,000}{33,000 \times 60} = 5 \cdot 5 \text{ horse-power},$$

the standard horse-power being taken at 33,000 pounds raised one foot high per minute,

$$33,000 \times 60 = 1,980,000 \text{ pounds per hour.}$$

Now take the amount of coal consumed by one of our best automatic steam engines in general use in our factories, averaging two hundred indicated horse-power per hour and burning six thousand pounds of coal per day of ten hours run.

This would be equivalent to a consumption of six hundred pounds of coal per hour, and the consumption per indicated horse-power would be

$$\frac{600}{200} = 3 \text{ pounds of coal per hour.}$$

The average anthracite coal as delivered at the factory boiler-house contains, in round numbers, about eighty-five per cent. of carbon. If we neglect the other constituents, we may consider that instead of burning three pounds of coal per hour per indicated horse-power, we are burning eighty-five per cent. of three pounds, or about two and one-half pounds of pure carbon.

We are therefore generating

$$14,500 \times 2 \cdot 5 = 36,250 \text{ heat units}$$

and getting in exchange *one indicated horse-power.*

As before shown, one unit of heat is equivalent to 772 pounds raised one foot high and, therefore, 36,250 heat units are equivalent to

$$11,194,000 \times 2 \cdot 5 = 27,985,000 \text{ foot-pounds.}$$

This shows that we are burning coal sufficient to raise 27,985,000

foot-pounds, or fourteen horse-power, and are actually only raising 1,980,000 foot-pounds or one horse-power. Or, in other words, we are, in fact, only getting out of a first-class steam engine about *one-fourteenth* of the power we should do.

This shows also how important it is to have the combustion chamber properly arranged so as to burn the fuel to carbonic acid.

Economical Combustion.

Coal may be said to be consumed with the greatest possible economy when the whole of the carbon enters into combustion with no more air than is necessary to supply the combining oxygen. The best condition of combustion is the contact of carbon with oxygen and the presence of a high igniting temperature. To maintain a high temperature in the furnace, the combustion or chemical combination should be complete before any heat is abstracted from the gases. There should be no smoke, but simply superheated gaseous vapor, carbonic acid and nitrogen. The quantity of this last would then depend solely upon the thoroughness of the admixture of the combustible gases, so that each atom of carbon might come into contact with the requisite atoms of oxygen. When the atoms have combined, they should be removed as directly as possible, as their presence prevents the combustion of the unconsumed remainder. The best practical arrangements for effecting economical combustion are a furnace composed of a non-conducting material and a rapid draft through and about the burning coal. A furnace composed wholly of fire-brick is preferable, but other considerations frequently preclude its adoption.

The course of the current of air through the furnace should not be too direct nor its volume too compact. But the admixture of the gases will be better promoted if the air be admitted through a series of small jets into the combustion chamber, and if the current of gases be diverted from side to side by suitable obstructions placed in the furnace.

As boilers are now generally set in brickwork, the greater part of the air for combustion is generally admitted into the furnace through the grate-bars. The air-spaces between the bars must, therefore, be kept clear of clinker, ashes, etc., by the free use of the slicing-bar. It is of great importance, also, that the layer of coal upon the grate-bars should not be too thick, or the air will be unable to pass up through it, and it is also necessary that the depth of coal be of uni-

form thickness, otherwise a large quantity of air will be drawn in at the thin places and none at the thick, thus leading to the production of a large quantity of carbonic oxide which, although invisible, nevertheless contains partly unconsumed carbon.

With a properly constructed combustion chamber under the boiler, with air admissions above the grate-bars, the fire-door will not be required to be opened as often as a boiler set to receive its air supply through the bars only; as in the former a thicker layer of coal can be carried and less slicing will be required, thus producing less clinker, as the air admission is not obstructed by ashes and clinker. For, as a rule, the fewer times the fire-door is opened the better; not that the introduction of the coal in large quantities is to be recommended, but because each time the furnace door is opened there is a rush of cold air into the furnace, which tends to cool the combustion chamber and to bring on leakage of the boiler seams from the contraction arising from cooling.

Air Admissions.

As to *the* place for the admission of the air, a large number of experiments show that so far as effect is concerned it is a matter of indifference in what part of the furnace or flue it is introduced, provided the one essential condition is maintained of keeping the temperature of the fuel gases above the temperature of ignition. This temperature, according to Sir Humphry Davy, should not be under 800 degrees Fahrenheit, since below that flame cannot be produced or sustained. This, in fact, is the basis of protection in the miners' safety lamp. In practice, the air has been introduced at all *parts of the furnace and with equally good effect.* Its admission through a plate distributor at the back of the bridge and at the door end effected all that could be desired.

To raise the temperature of the air supply is my practice up to the point of ignition. I recommend the construction of a double passage or air-flue in the brickwork on each side of the furnace, by which the air drawn in at the front passes the whole length of the side walls and back again to the fire, where it is delivered upon the fuel at a high temperature, having in its journey through the hot bricks become considerably increased in volume, due to its absorption of heat, so that it becomes an actual *hot blast* upon the coals, and the result altogether is a very perfect combustion of the coal and a total absence of all smoke in the use of bituminous coal, logwood cuttings, spent tan, etc.

Grate Surface.

The area of the grate surface should be proportional to the quantity of coal which is to be burnt upon it in an hour, and the height of the chimney, taken in connection with the temperature of the heated gases, determines the *rate of combustion* per square foot of grate.

The grate should bear a certain proportion to the section of chimney, which is about 8 to 1.

Heating the Feed Water.

The ordinary temperature of feed water is about 60 degrees Fahrenheit, and at this temperature the *heat* required to generate a pound of steam is

$$180 - 60 = 120 \text{ units of heat.}$$

By using the *heat* of the exhaust steam to raise the temperature of the feed water, a very large saving is effected. The temperature thus attainable is limited by that of the exhaust steam, with non-condensing engines from 140° to 200° with a well-constructed heater. With condensing engines the feed water is usually taken from the condenser at about 100° by which means about 40 units of heat per pound of steam are saved.

With non-condensing engines, having a good heater for the feed water to pass through, the latter can be raised to 200° Fahr., producing a saving of at least 50 units of heat per pound of steam.

This is not the only advantage gained from the use of hot feed water, as at 200° Fahr. much of the solid impurity in ordinary water is deposited in the heater in place of being passed into the boiler, where its deposition retards the transfer of *heat* and lessens the efficiency of the boiler. By heating the feed water and thus reducing the *heat* per pound of steam, a higher efficiency may be produced from a given boiler, owing to the less rate of transmission per unit of heating surface.

The Water Supply for Boilers.

The feed water should be put into the boiler as hot as possible and at a point *near* the *surface* of the water inside the boiler. The cold water descends, but before reaching the bottom it will have become heated, thus keeping the boiler at an even temperature. If the water pumped in be low in temperature it should be well distributed through a perforated pipe in the mass of water in the boiler and not allowed

to impinge on any portion of the metal of the boiler, or it will be liable to crack the plate from continual action of contraction and expansion. Water pumped into the boiler near the bottom does not rise until it becomes heated, and this plan of feeding the boiler tends to keep the bottom of the boiler cooler than the other parts.

The best plan is to have a well-constructed feed-water heater, as its cost is more than balanced by the increased durability of the boilers; and as the feed water is generally heated by the exhaust steam from the engine, which would otherwise be wasted, the difference or saving between using feed water at 70 degrees and say 200 is about *twelve per cent.* of the coal consumed in making steam; or a given weight of coal being used in both cases, about *fifteen per cent.* more effect will be obtained from feed water at two hundred degrees over that of cold water. The heating of feed water amounts to the extension of the heating surface of the boiler, but it has this advantage that the heating surface of the apparatus is kept free from soot while that of the boiler is not. It has been found by experience that each ten degrees of heat so imparted to the water saves one per cent. of fuel.

Temperature of the Escaping Gases.

The temperature of the escaping gases *must* exceed that of the steam in the boiler at least fifty degrees, otherwise there will be a loss by radiation.

Prof. R. H. Thurston says: "The maximum conductivity, or flow of heat, is secured by so designing the boiler as to secure rapid, steady and complete circulation of the water within it, . . . and securing opposite directions of flow for the gases on one side and water on the other."

Chimney.

The most important factor for producing steam economically is the chimney, for on it we depend for the proper combustion of the fuel; for without intense draft perfect combustion cannot be accomplished. The intensity of draft is, however, independent of the size of the chimney, and depends upon the difference in weight of the outside and inside columns of air. This is usually stated in an equivalent column of water, and may vary from zero (0) to possibly two inches in height. It varies directly with the product of the height into the differences of temperature.

The intensity of draft required varies with the kind and condition

of the fuel and the thickness of the fires. Wood requires the least, and fine coal the most. To burn the latter to advantage a draft of about a $1\frac{1}{4}$ inch of water is necessary, which can be obtained by a well-proportioned chimney, one hundred and fifty feet to two hundred feet high.

A rapid draft is in one respect equivalent to a large fire grate area (the higher the chimney the less area of grate will be required), since it equally enables more fuel to be burned in a given time, and thus increases the power of the boiler in generating steam. A quick draft, however, has this advantage, that, inasmuch as the temperature of the furnace is higher when the same quantity of heat is generated in a small space than it will be when generated in a large space, the heat is transmitted much more rapidly to the water of the boiler in the case of the strong draft, by reason of the higher temperature thus obtained. As there is more heat transmitted in the region of the furnace, in the case of the strong draft, there will be less remaining to be transmitted in the region of the flues; or, in other words, the flues will have less work to do, and they may either be made shorter, or the heat will be more thoroughly absorbed.

A *low* fire is never economical; the same quantity of *fuel* burnt at a *high* temperature would do more work. A chemist will get *fourteen pounds* of water turned into steam by one pound of carbon; but in engineering the most that can be attained is *twelve pounds of water* to steam by one pound of carbon.

Long flues absorb more heat than small, as both the volume and intensity of the heat are greater with equal surfaces. This shows the importance of having a high chimney, in order that smaller flues can be used to produce the same result as larger ones with a corresponding less height of chimney.

The Theory of Chimney Draft.

The upward movement of warm air and gases of combustion in chimneys is caused by the difference in density of the external air and of the enclosed gases. All permanent gases expand 0·0020284 (or $\frac{1}{493}$) of their volume for each degree Fahr. of difference in temperature, and the density in weight per unit of volume decreases as the volume increases; that is, if the volume is doubled the weight per unit of volume will be only one-half of the original weight.

Suppose a parallel tube, *A B*, Fig. 3, to be of one square foot cross-

section and 100 feet high, filled with air of the same density and temperature as that surrounding it; the air pressure will then be in equilibrium in and outside of the tube, namely, 14·7 pounds to the square inch, or 2116·8 pounds to the square foot, which is the pressure at the base, *A*.

All gases exert pressure equally in all directions, so that the downward pressure of the air in the tube at *A* is balanced by the upward pressure of the surrounding air; consequently no motion will ensue.

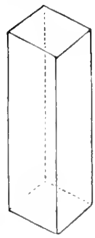


Fig. 3.

The weight of a cubic foot of dry air at 60° Fahr. is 532 grains; or, the air in the tube (100 cubic feet) would weigh 53,200 grains, or 7·6 pounds. That is to say, the pressure per square foot at the top, *B*, of the tube would be only 2116·8 — 7·6 = 2109·2 pounds, the force with which the enclosed air presses upwards at *B*, and is balanced by the pressure of the air above, so that no motion will ensue.

Now let us heat the air in the tube from 60° to say 360° Fahr., a difference in temperature of 300°. The enclosed volume of air will be expanded to

$$1 + 300 \times 0{\cdot}0020284 = 1{\cdot}60852 \text{ volumes.}$$

The actual volume in the tube is 100 cubic feet expanded to 160·852; that is, 60·852 cubic feet will be ejected from the tube by the force of expansion of the heated air, but the weight of the remaining 100 cubic feet of air in the tube will be only

$$\frac{7{\cdot}6}{1{\cdot}60852} = 4{\cdot}714 \text{ pounds,}$$

or $7{\cdot}6 - 4{\cdot}714 = 2{\cdot}886$ pounds less than the upward pressure of the surrounding air at the base, *A*. The heated air in the tube will consequently be set in motion upwards by this motive force of 2·886 pounds, by the cool air entering under the base, *A*.

This is the principle upon which the so-called "draft" is generated in chimneys, which in reality is no draft, but a pushing of the cold air under the fire-grate, and by expansion of the heated air, which drives the mixed gases of combustion up through the chimney.

In our first illustration the cold air from underneath the tube will soon drive out the heated air and establish an equilibrium of pressure, by which the upward motion is stopped; but in a furnace the enclosed

air and other gases are continually heated, which results in a continual motion upwards in the chimney.

Intensity of Draft.

The intensity of draft is independent of the size, and depends upon the difference in weight of the outside and inside columns of air. The intensity or degree of heat produced by fuel varies in proportion to the rate at which it burns; the greater the draft a greater amount of work will be produced from the same fuel. This goes to show the importance of a high chimney.

Draft of Chimneys.

The *power of the draft* is directly proportioned to the height of the chimney, and the velocity with which the external air flows in to supply the draft depends upon the temperature of the ascending gases. The higher the temperature is the lighter will the gases be, and consequently create a stronger draft through the grate bars. This velocity is proportional to the square root of the height of the chimney.

Air at 520 degrees expands to double its volume at 32°. At this temperature, therefore, within the chimney, the velocity with which the external air will pass through the grate bars would be proportional to the square root of half the height of the chimney, which, expressed in feet per second, is equal to eight times the square root of half the height of the chimney, or

$$V = 8 \sqrt{\frac{H}{2}}$$

Example.—The height of a chimney is $H = 128$ feet, and the temperature of the gases $T° = 520°$. What will be the velocity of the air through the grate bars?

$$V = 8 \sqrt{\frac{128}{2}} = 64 \text{ feet per second.}$$

As a general rule for calculating the draft at any temperatue, the following is near enough for all practical purposes

$$V = 8 \sqrt{H a (T° - t°)}$$

In which

$H =$ the height of the chimney, in feet.

$h =$ the difference of the height of columns of equal weight.

V = velocity of the escaping gases, in feet.

g = gravity, a constant number = 32·17.

T° = the temperature of the warm air.

t° = the temperature of the cold air.

a = the coefficient of expansion of air for one degree of the thermometer at 32° will be $\frac{1}{493}$ = 0·002028 under constant pressure.

$h = H\,a\,(T^\circ - t^\circ)$.

Area of a Chimney.

The area of a chimney for ordinary purposes may be determined by the following formula:

$$A = \frac{0{\cdot}3\ \text{HP} + 10}{V\,H} \quad \text{or} \quad \frac{\square + 10}{V\,H}$$

HP = horse-power of boiler.

A = area of chimney, in square feet, at smallest part.

$\square$ = area of grate, in square feet. The constant 10 allows for the difference in friction between large and small chimneys.

Height and area are the only elements necessary to consider in an ordinary chimney.

Expansion of Gases.

Unlike solids, gases expand equally for an equal increase of temperature, as measured by a thermometer. The experiments made by Rudberg, and confirmed by Regnault, show that atmospheric air, heated from the freezing to the boiling point, expands at the rate of $\frac{1}{493}$ or 0·0020234 for each degree Fahrenheit, being the increase of volume under constant pressure.

If we wish to ascertain the volume of v = 200 cubic inches of a gas at t° = 60° would occupy at T° = 100 degrees, we must remember that it does not expand $\frac{1}{493}$ of its bulk, at 60° for each degree, but $\frac{1}{493}$ of its bulk at 32°, and so on.

$$V = v\left(\frac{T^\circ - t^\circ}{493} + 1\right) \text{ and } T^\circ - t^\circ = \frac{493\,(V-1)}{V}$$

V and v = volume of dry air of temperature t° and T°.

$$V = 200\left(\frac{100-60}{493} + 1\right)$$

THE UNIVERSALITY OF VIBRATIONS.

By C. C. Haskins.

[Read at the meeting of the Chicago Electrical Society, May 15, 1882.]

Vibrations, in the most limited sense of the term, are defined as minute reciprocal motions of the particles of an elastic body when they are thrown out of equilibrium. Oscillations embrace a class of movements which may be termed vibrations of greater dimensions—the two differing only in degree. These may traverse vertical arcs or horizontal curves, parts or the whole of circles or ellipses. Amplified still further, we find movements embracing extended cycles of time, yet ever returning to a former condition or position. These are all, generically speaking, vibrations, differing only in the one element of time. We may go farther and include as vibrations all that class of changes or motions which have the one common similarity of starting at a given point, origin or condition, and having accomplished a change of place, form or position—a cycle of movement or transition—returned to their pristine status; again and again repeating this round of differing phases.

These periodic rounds, whether comprising two or more changes, whether molar or molecular, I have classed as vibrations, and within this scope I include the movements of elastic bodies, springs, chords, gases, etc., the segmental action of suspended bodies like pendulums, the gyratory movements of storms, the progression of planets in their orbits, and those chemical changes which are ever active in nature, producing combinations in the mineral, animal and vegetable world, by which the various conditions of growth and decay so constantly and regularly succeed each other.

These mutations—now noiseless, hardly perceptible in their slow progress, at other times bold, rapid even to instantaneity—eventuate in the same accomplishment, the restoration of the elements to their simplest form and their recombination in the chemical world, in the world of motion—to repeat for all time this round of change, this following in the beaten path of nature's ages—periods of time of which the mind of man can take no cognizance.

Take an example: An internal chemical commotion occurs beneath the crust of the earth's surface. Inharmony among the existing elements as combined results in greatly increasing the volume of these,

and the stored up energy heretofore confined is set free. This energy is expended in the line of least resistance, and the result is an upheaval of the earth's surface. A mountain is born. One limit of the vibration is reached.

Rains descend upon the upheaved surface, penetrate the crevices of the rocks, dissolving and carrying portions of these in solution to lower levels. Winter, with its irresistible frosts, widens the seams in the most obdurate rock-formation, crumbles, and slowly—but surely—reduces them to a comminuted condition where they may again become sedimentary rock, once more to be subject to the will of the great plowman Nature, whose implement is the earthquake, whose furrows are the mountain ranges.

Within the earth, deep hidden from human ken, where the rock-formation is of a nature to permit, huge caves are in progress of formation. Metallic bases, combined with acids, in the form of flakes or nodules, absorb the infiltrating moisture from above, and the acid, having a greater affinity for the alkaline rock than for the metal, leaves the latter and uniting with the former produces a new compound, which, being soluble in water, is carried away in the outgoing current. The metal, too, forming a new combination with the oxygen of the water, is similarly disposed of and a cavity is formed in the bowels of the mountain. Here is the nucleus for a cave. In this way Mammoth Cave was formed; and Nature, tireless designer that she is, is still at work making additions and modern improvements in these her magnificent underground palaces.

The transitions of water are familiar to you all. As rain it descends from the clouds, it penetrates the earth, evaporates, and is again precipitated upon the ground. It may assume the form of ice, or snow, or clouds, or steam—yet it is still water—the two combined elements of its existence are ever present. We may separate these by force and the same force will re-unite them. We may rarify the fluid by heat, or condense it by the withdrawal of that force, but it remains water still. We have added nothing which did not exist before. We have taken away nothing. Thus we may ring all the vibratory changes on any substance in nature. We destroy nothing, we add nothing, and the conditions which wrought former changes and produced previous results will invariably repeat the phenomena in obedience to the unwavering fiat of vibratory law.

Our sulphate of copper batteries give us a fine exemplification of

such changes from an electrical and chemical standpoint. Sulphate of copper, a combination of sulphuric acid and metallic copper, is soluble in water. This forms one of the elements of our battery. Metallic zinc is used for the other. These are placed in water, and the connections being made, which render the circuit complete, the stored up energy of the elements is released, the salt of copper is dissolved, and its component parts, sulphuric acid and metallic copper are separated. The copper, restored to its metallic form, is deposited at the bottom of the jar. The sulphuric acid attacks and combines with the metallic zinc, producing sulphate of zinc, which is held in solution by the water. Now, when the action is continued until the elements are consumed, by evaporating the water and weighing the residuum, we will find just as much copper, and zinc, and acid as originally existed, but the combinations have been altered, and by still farther manipulation we may separate the acid and the zinc, reducing the former to a liquid form, and the latter to its metallic state, and recombine the acid and the copper so as to complete the cycle of vibration and erect a second battery, similar to the former, from the same elements.

Water in motion presents a fine illustration of one form of vibration. If we carefully observe a floating body, a chip, or a bird, on the dead swell of the sea, we shall find that the water motion does not carry the object away from its position, but merely compels it to rise and fall perpendicularly. A rope suspended from one extremity, when shaken, will give us the same wavy motion. The vibratory undulations will run from the one extremity to the other, until overcome by gravity, they cease to be noticeable.

The vibrations of a large body of water, like the sea, are complex and of nearly every degree of amplitude. Not a breath of air passes over it; not a ray of light or heat penetrates it; not a sound is produced at the surface, within or below it, but creates a vibratory movement in the mass. The waves, the tides, the currents, the evaporation, the very color of the sea are as strictly amenable to vibratory law as are the strings of the violin or the pipes of a church organ.

Vegetable life furnishes another familiar illustration of vibratory law—this cycle of existence.

At first the seed, selecting and absorbing the proper nourishment from the surrounding soil, chemically changing the force thus released to its own use, it increases its dimensions, sending certain portions of its organism in search of farther food below the surface, and directing

other members upward until its growth is finished, its mission ended, it first ceases to provide for the continuance of its species, then dies and decays and is returned to the soil and the air from whence it came. It has resolved into its primal elements and completed its vibratory cycle. Yet there are minor vibrations in constant motion during its entire life period, each complete in its own sphere of action; each to an extent a necessity, an element in the grand result.

Within the minute vessels, those veins and arteries that lead from the tiniest rootlet to the uttermost extreme of the highest leaf on the tree, what quantities of life-blood have been carried up from the ground for its sustenance and refreshment. Thousands of hogsheads of water have been transported to the tops of the forest monarch during its years of growth, carrying with them the elements required for the food and growth of the wood, the bark, the leaves and the fruit, in addition to the forced contribution which the atmosphere has been compelled to contribute, and these elements have been appropriated, separated, assigned and assimilated, all in obedience to and by the aid of vibràtory law.

The summer's growth, the winter's rest, the ripening and fall of the leaves and fruit, regular as are the seasons, are but so many annual vibrations in its period of existence.

Its various parts, too, are in constant motion, and whether we note the swaying trunk and bending limbs contending with the wintry gale, or the pendulum leaves gently waving in the summer breeze—vibrations in some degree or form are still the same ever present accompaniment of its daily life.

As in the tree, so in the tiny blade of grass. Could we but invent some method of multiplying our hearing capacity in the same degree as the microscope has enlarged the field of human vision, every blade of grass, every clover stalk and daisy stem would roar with the laughing cataracts that rush through the little veins and arteries, and run the mimic mills to feed and paint their gaudy blossoms.

As in vegetable, so in animal existence. Birth, life, death, decay, follow each other to make up the vibration of physical existence with all animate nature. It is difficult to designate a function pertaining to animal life that is beyond the control of these laws. We breathe; respiration is vibratory. Our blood flows in pulsations. All nervous excitation, whatever the sense—sight, hearing, taste, touch; even thought, that highest of all nervous sensations—all these are clearly

vibratory in their action. Why, even our organs of locomotion are but vibratory appendages, like the fins of the fishes or the wings of the feathered world.

A clear conception of distance, beyond a limited range, is difficult of accomplishment. Even comparison with familiar areas or spaces, when applied to extended intervals, gives but unsatisfactory results. By day we behold the sun which lights and warms the earth from a distance of nearly one hundred millions of miles away. By night we behold the lesser lights, the number of which, including the telescopic stars, is estimated at no less than seventy-five millions. Many, very many of these are vastly superior in size to our own sun (which has over one million times the volume of our earth), yet by reason of the great distance of these immense bodies they appear to us as mere points of light.

The dog star (Sirius), the brightest star in the northern heavens, has the volume of sixty of our suns, yet such is its immense distance, about one hundred millions of millions of miles away, its brilliancy is much inferior to that of the planet Venus, which is one-tenth smaller than the earth.

Now, to come back to the sun, the centre of our solar system, we see it surrounded by a series of planets, each performing revolutionary vibrations around it, their cycles of movement varying with their varying masses and distances, and these again in many instances carrying with them secondary bodies, each moving with uniformity the most precise, harmony the most complete, and with a grandeur awe-inspiring.

The planet on which we live has each day since its creation whirled in space, completing its diurnal revolution on its axis, and each year its annual movement about the sun, lighted and warmed by vibratory force from that great luminary, held in its position by vibratory law. And the sun, too, revolving upon its axis in about twenty-five and a half of our days, moves in an orbital track about some other sun, carrying with it the entire system of which it is the centre; and this again is supposed to be a system dependent upon another, and another, until there is no conceivable limit.

It is beyond the grasp of the human mind, until infinity is explainable, until we are enabled to comprehend an existence which has neither beginning nor ending; and all these movements are amenable to gravity, which holds and controls these immense unnumbered masses

in space; that sends them forward on their untiring journeys, over paths without tracks, with an uniformity and exactness to excite a feeling of wonder and admiration in the most skeptical human mind. Yet our own solar system has no mean or insignificant proportions when we consider the extended vibrations of comets in their annual revolutions round our sun.

One of these astronomical puzzles, of which the orbital elements were computed by competent authority, requires no less than 3380 years to complete a single oscillation. When we remember that these wanderers are sometimes accompanied, during a portion of these orbital trips, by an attendant having a lineal measurement greater than the distance from the earth to the sun, we are struck dumb with astonishment and reverence at the immensity of the mechanical movements of these whirling pendulums of God's Eternal Clock.

Everywhere in nature there exists a substance of infinite elasticity and extreme tenuity, which surrounds the atoms and permeates every so-called solid. It fills all space throughout the universe. This substance is known as luminiferous ether. Vibrations from luminous bodies are taken up by it and transmitted by wave motion. Light is conveyed by it something similarly to the manner in which sound is conveyed by air waves with, however, this marked difference: while sound waves move in one direction those of light move at right angles to this—the former being, in scientific language, longitudinal while the latter are transversal. The mechanical properties of this ether are rather those of a solid than of an air.

The vibrations of this extremely tenuous and elastic substance are, from its very nature, capable of inconceivably rapid movements and, from like causes, it is never at rest. The rays of the sun are brought to us at the rate of about 187,000 miles in a second. Sir John Herschel estimated that a cannon ball would require seventeen years to reach the sun, while light requires but eight minutes to traverse the same distance, and that while the swiftest bird would be nearly three weeks in flying around the world, light would make more than the entire distance for each stroke of its wing.

Light, pure and colorless, as it is given to us, is susceptible of divisibility. Nature does this for us in a most complete manner in the rainbow. Artificially this is done by the triangular prism, giving us the seven hues once known as the primary colors.

The principle which underlies this experiment is this: the different

hues have different rates of vibration and different angles of refraction. The prism receives the ray of white light and, refracting it, breaks it up into its component parts, throwing the different colors at differing angles, and consequently at varying distances, upon the screen. Following up the result thus obtained led to the discovery of the spectroscope by means of which the component parts of the blazing sun and the light from the fixed stars are as perfectly analyzed and recognized as if manipulated in the laboratory of the chemist.

The solar spectrum shows peculiarities aside from colors which, like these, do not extend the entire length of the image on the screen. Beyond the rays which are there visible to the human eye, where all seems colorless and dark, at the one extreme of the spectrum rays powerful for chemical effect are found by the photographer and the chemist, while beyond the opposite or red extremity are found invisible rays of excessive heating power.

The ultra-violet rays, which to us are opaque, have, by late interesting experiments by Sir John Lubbock, proven to be less opaque to some classes of insects, than even the yellow rays. We can have no conception of what the ants see in that portion of the spectrum.

Light vibrations, like those of heat and sound, may be deflected from their course. We see the sun, a star, or a candle by its own light, which reaches us in a right line from its source. Were it not for reflection, the light of the sun would be entirely shut off wherever a shadow now exists.

Echoes are illustrations of the reflections of sound vibrations. The long rolling thunder in a summer storm, succeeding a flash of lightning from one of nature's condensers, is but the reverberation of sound waves, hurled back and forth from cloud to cloud until silenced by absorption.

The tone of an engine bell, or the whistle of the train you are passing on a railway, rises rapidly to a higher pitch as the trains approach and sinks again as they separate. The diminishing distance in the first instance increases the number of vibratory waves that strike the ear in a given time, while the receding trains diminish the number impinging upon the listener's ear during the same period, and the pitch of the tone we know depends upon its rate of vibration. The tone of a steam whistle is often varied by the engineer, who gradually opens and closes the valve, thus increasing the vibratory rate or

decreasing it, sometimes carrying the whistle tone nearly or quite through an octave.

Vibrations may be absorbed. It is to this fact that we are indebted for the hues of all nature's beauty by field and hill, by glade and stream, where but for this provision all would be tiresomely similar and sombre. This peculiarity of vibrations is made available by musicians in the use of the soft pedal of the piano and the mute on the cornet. In the acoustic telephone you all know how carefully the sound insulators must be adjusted to prevent the deadening of the vibrations and so make even a tolerable success of it. Heat vibrations are readily disseminated and dissipated by absorption; vibratory waves moving rapidly or slowly according to the relative capacities of the source and the recipient.

Some recently published results of experiments by that eminent scientist, Chas. W. Siemens, with the electric light as an aid to vegetation, are interesting from this point of view.

These experiments extended over a period covering considerably more than a twelvemonth, both inside a greenhouse and in the open air. It soon became apparent that the open air plants, which received the light rays through the glass forming the frame of the lamp, were far more thrifty and in better general condition than those under cover which were exposed to a naked light.

The first attempted explanation of this fact was the assumption that the increased production of nitrogenous and carbonic compounds was in excess of the needs of the plants, and so acted destructively. All attempts, however, to remove the difficulty, by ventilation and otherwise, proved futile. Finally a clear glass globe was placed around the light and an almost marvelous change occurred in a single night. A sheet of glass was then placed so as to intercept the rays from one portion of the plant, while other parts of the same plant received the free rays. In twelve hours a distinct line of demarkation showed where the two sets of rays joined—and yet this difference was only the result of the interception of a thin sheet of clear, uncolored glass. So far as the eye could detect no light was absorbed, nor was its color perceptibly changed, and yet a decided advantage was gained by passing the rays through this thin transparent medium.

Following up the hint thus arrived at, the learned investigator arranged the conservatory so as to submit different portions of this to

the action of light transmitted through blue, red, yellow and transparent glass, and the uninterrupted rays direct from the lamp.

Under the clear glass the most satisfactory growth was induced. Next in the order of success came the yellow; the red light produced a spindling growth with sickly yellowish leaves, while the blue exaggerated these results; and the naked light, least successful of all, produced a dark and partly shriveled growth of foliage.

Now, in all these experiments, to the absorption of invisible rays, the arresting of the vibrations of some part of the beams of light from the electric arc, are due the curious and marked results obtained.

The air surrounding us is in constant vibration. Heat, light, sound, are constantly disturbing and varying its condition. The sound of my voice, originating in a muscular movement of the throat, is carried by the wave motion there communicated to the air, and thence to the uttermost parts of the room, with comparatively little effort. Yet, in doing this, I am effecting a sensible mechanical result on a gaseous body exerting a mechanical pressure of fifteen pounds to the square inch in every direction. These vibrations are sufficiently low in their rate of movement to produce an effect on the auditory nerve of the human ear.

Man has been classified by some satirist as a "two-legged, boasting animal," and education has taught us to believe that the human race is superior, in every respect, to the so-called inferior creations of nature. We claim to be nearer, in every way, to the great Creator of the world, and highest in the scale of God's handiwork.

We are saved from mortification and exposure by the fact that the power of speech, that is language which we can interpret, has been denied to the rest of the animal world. Could they but speak to us in our language, or could we but translate theirs, they would tell us of sound vibrations so rapid that the dull ear of humanity is incapable of receiving them.

The range of vibrations which are appreciable to the human ear is limited between sixteen and forty thousand per second. That is, a vibration which completes sixteen cycles in a second, or more rapidly until it accomplishes forty thousand in the same period of time, is, save in anomalous instances, appreciable to the human ear; and these limits embrace the rates of vibrations of all appreciable sounds. Above or below these, to man, all is silence.

With an instrument similar to the siren, specially constructed for

the purpose, Sir John Lubbock created the utmost consternation among the animals of a zoological collection and killed great numbers of insects, while no noise was heard by those standing near the instrument, nor was any disturbance experienced from its action. The rate of its vibrations required a more delicate nerve organization than we are possessed of, to recognize their presence.

Perkins, the inventor of the steam gun, without recognizing the fact, arrived at the same result, namely, the production of rates of vibration above the capacity of the human ear, in the course of his experiments with steam in a high state of tension, from the standpoint of the phenomena of boiler explosions.

In a boiler of sufficient thickness and strength to secure perfect immunity from explosion, he drilled a hole not larger than a fine needle. He applied gradually increasing heat beneath this boiler until it reached the highest point attainable by the means at his command. As the heat increased these phenomena presented themselves in the order named. At first, vapor exuded from the minute orifice, then white, followed by blue steam, accompanied by hissing, succeeded by a low whistle. The sound increased in both force and shrillness, rising finally to an almost deafening shriek which the experimenter says could be heard a mile. Then the sound grew gradually fainter until silence ensued, the quantity of visible steam decreasing until neither sound nor steam were appreciable, but the circumference of the orifice became hotter and eventually assumed a bright cherry-red color. The rate of audible vibrations had been passed and some of these were now being reconverted into heat in their passage. The source of heat was now removed and the various results were again arrived at, but in an inverted order of succession.

Had Perkins been investigating vibratory law, instead of boiler explosions, he would doubtless have seized upon these capital illustrations of the conservation of energy.

His theory of the silence and the non-issuance of steam at the point of greatest pressure was, that the heat had, by expanding the steam particles, so enlarged these that they were unable to pass the orifice which had become partially closed by the expansion of the metal surrounding it.

The human eye compares no better with those of a lower animal creation. The birds, many of them, and especially those of the family to which eagles, hawks and vultures belong, are furnished with

telescopic eyes, by which variations of distance—to what extent we know not, but we do know they are great—are almost instantaneously compensated for by focal changes in the eye.

I have seen a hawk dive from the top of a high tree and seize a mouse upon the ground quite near me, before the latter could reach a hiding place ten feet from its nest which I had just overturned; and yet from that bird's lookout to me was a distance so great, I much doubt if I could have seen a squirrel to recognize it with certainty.

Some one has said, in substance, of the human eye, that it answered very well for want of a better, but that an optician who would call attention to a specimen of his work which combined so many imperfections as the the best human eye always includes, would lose, rather than gain by his advertisement.

The "eyes of science," as Proctor has so aptly designated those optical appliances, the microscope, the telescope, the camera, and others, are far more perfect in many regards than those combinations of lenses nature has furnished to humanity. The human eye is impressed instantly, but it ordinarily requires about one-sixth of a second to lose the perfect impression of any object, and this persistence of vision blurs by interference the next subsequent impression.

A meteor in the sky is to us, in its rapid movements, a luminous line, while we know that its form is globular. A sky-rocket produces much the same impression, and a fire-wheel, after its pyrotechnic fires are extinct, still shows a ring of fire, while its motion is dying down, if the case has but a spark upon it. Sparks from burning charcoal, or from a chimney, are streaks of fire; and a discharge from a Holtz machine, like that from one of nature's larger accumulators, is ever a streak of lightning. The spokes of a carriage-wheel are blended in rapid motion and the wheel assumes the appearance of a disc, while the action of a horse, at a rapid pace, is never well defined by the retina, except where an instantaneous illumination is followed by absolute darkness. Yet the camera of the photographer is competent to catch and preserve the attitude of the swiftest moving animal. Perfect representations of the fleetest racers have been thus secured with a plate exposure of such short duration that the entire animal has been pictured in the air, not one foot touching the ground.

Photographs of the sun have latterly been taken so nearly instantaneously as to show details impossible of procurement by any other method, and which, of course, had never been known before.

And the eye of science is equally superior to the human organ in other important regards. Without wearying, without even winking, it will hold its unflinching gaze, as in the case of photographing nebulæ, where two or three hours are required to fix an impression of these faint bodies; and this, too, while most ingenious apparatus is required in combination with it to compensate its visual direction for the complicated movements of the earth, during the long exposure.

In various portions of the world are found caves, the waters of which are inhabited by sightless fish—creatures possessed of only rudimentary eyes—in other words, so imperfect is their visual organism that to all intents and purposes they are totally blind. The light of day never reaches them, yet they are capable of finding their proper food, escaping from danger, hiding or fleeing when pursued; in short, accomplishing their fish destiny in much the same manner and apparently with as much success as their more fortunate and higher developed cousins in the waters above ground.

Some experiments made with specimens of these fish showed interesting results. They were confined in an aquarium in which was placed a considerable quantity of ragged rock, selected and arranged to form the best possible dark-hiding places and thus adapt their forced existence, as nearly as might be, to their natural requirements.

It was noticed that in all their movements they passed freely back and forth, around and among the rocks, without hesitation, even when suddenly startled by concussions, noises, etc., and they were found to be extremely sensitive to the least disturbance. Touching the water never so lightly with a broom-straw caused them to hide at once.

A fish of a different variety, but possessed of perfect vision, was procured and placed in the aquarium, when immediately a new series of phenomena presented themselves. As the strange fish struck the water, the poor blind creatures, instead of shrinking with fear and seeking a hiding place, at once assumed the offensive and gave chase to the intruder, who fled, evidently conscious of danger. It practiced all the knowledge it possessed in doubling and turning the angles and threading the intricate passages among the rocks, and was closely followed until overtaken and destroyed by its sightless enemy. In all this chase the track was never lost, the threatening projections of rock were evaded as readily by the pursuers as by the pursued, and no evidence was adduced to indicate that the one had not visual powers as perfect as the other.

Now, vibrations, in some form, guided these sightless creatures in the pursuit of the intruder. Whether those pertaining to smell, or feeling, or sound, we know not—we can only conjecture.

A blind man, one who from birth, or for many years has been deprived of sight, is to some extent compensated for his lack of vision by increased sensitiveness of other faculties; but these never reach the perfection shown in the experiment mentioned.

The brain, in the higher developed types of animate nature, we consider the seat of the mind, of thought, of that will-power which controls, through a system of vibratory nerve telegraph, all physical action. Physiologists tell us that at this centre of life action the record is made of all outward impressions.

In telephonic parlance it is a sort of central office, whence all responses are made, and to which all calls are sent. These delicate lines are no more wonderful than varied in their capacities and adaptations to rates of vibratory action, each within its own range or sphere.

The auditory nerve, divided into some three thousand harp-strings, is incapable of receiving impressions from finer vibrations than those pertaining to sound. The delicate organism of the inner ear may be injured so that ordinary audition is impossible; yet, if the little harp be intact, the proper rates of vibration may be communicated to and received by it through other nerves which lie in the immediate neighborhood. A deaf person may often be made to hear the twanging of a stretched cord or wire, one extremity of which is held in the teeth. The sound is communicated through the bones of the head to the inner ear. The audiphone held to the face or any fleshy part of the person will give no result, and it is valueless to those whose teeth are "marvels of art." Nor will the audiphone accept the lower jaw as even a passing good substitute, for the mechanical separation of this from the head bones interposes at the joint an imperfect conductor.

Pungent odors often produce marked effect upon the pneumogastric nerves, while a derangement of these latter may sometimes produce an effect upon the olfactories. In all these cases the vibratory effects are secondary rather than primary in their nature and power.

In the lower animal organisms, though no brain, as such, is found, there still exists, for all the requirements of these less perfect creations, a system of mental action by which all needs are provided for. Fear,

hunger, the baser passions, maternal instincts, etc., are all more or less perfectly developed.

Still farther down the scale we find in vegetable life, action which so closely approaches to that of sentient life as almost to obliterate the dividing line between the two. An acorn, starting on its life journey, finds itself opposed by unpropitious circumstances. The soil is unfavorable—a rock impedes its progress. The weakly little shoot, deterred by nothing, sends out its tiny rootlets, downward or laterally as the case requires, but always in the right direction, in search of the proper nourishment. The plant root is a faithful, honest commissary. Prevailing winds threaten its overthrow when the little oak has attained to more respectable dimensions, and now it displays the talent of an engineer, throwing out strong bracing roots, yet always in the proper direction, to prevent the threatened disaster.

See the fruit-bearing tree in the blooming season. Could every flower there become a perfected fruit death would inevitably ensue from the ill-proportioned weight on the boughs. What is the remedy? The tree, as if it reasoned with itself, seems to say: "I have provided for accidents which have not befallen me, and I have now a greater call upon my energies than is safe for my health and the good of my offspring." It dooms certain of the germs to destruction. There is no law against infanticide in nature, and the condemned, deprived of the requisite nourishment, wither and fall. Again and again, during the season, does the tree enact the several roles of accuser, judge and executioner, until it has decided what shall finally remain, and then the work of growth and ripening goes on swimmingly. It is true there are occasional mistakes made, more being undertaken than can be carried to a successful conclusion, or less than an average number of germs retained. In the former case the rule of the greatest good for the greatest number is adopted, while in the latter everything is done for the few; quality and perfection being the apology for meagre quantity.

Trees make mistakes as well as men, but trees have no brains.

Minute differences in vibratory rates are capable of producing most striking results. In musical tones, doubling the rate of vibration invariably raises the tone one octave, and every increase or decrease of the vibratory rate of a tone changes its pitch proportionately. But the same absolute pitch sounded upon two different instruments pro-

duces entirely distinct impressions upon the ear. Why? Because of the overtones, the combinations of minor vibrations, which are ever the accompaniment of any tone. These minor vibrations are combined in different proportions in different sound sources. A silver flute has not the same tone as one of wood, and the clarionet is unlike the violin in the quality of its tone. This quality of tone is almost endless in the variety which it permits in music. But material has not alone the control of this peculiarity of tone quality. Form has much influence. It lies at the bottom of those differences in the human voice by which we are enabled to select musical or unmusical vocal efforts. By the quality of a voice we may recognize an acquaintance in the dark, even after years of separation.

A careful study of the quality of the human voice is as necessary in the selection of a vocal band as is the quality combination in an aggregation of instrumental musicians. The fewer the number, too, the more apparent will be the want of that finer harmony, the pleasing effect of properly selected quality in the voices or instruments, if this study is neglected. Understand, I do not speak now of the ability to correctly reproduce every note, but a capacity to make these notes so produced blend harmoniously as a whole.

The finest singer, in advancing years, may, while retaining all the accomplished knowledge which education and practice have wrought, be very unmusical in vocal effort by reason of changed quality of voice.

Another marked result in music is chargeable to these overtones or sub-vibrations. Musical instruments are imperfect in their construction. Theoretically we assume that the scale is made up of a certain number of steps or tones and half-steps or half-tones, and that certain differences in the number of vibrations will produce a note or a half-note above or below a given tone. But you who have been compelled to listen to a piano or organ tuner know that he is a longer time at his work than would seem necessary were this the fact. Practically, there are a certain number of vibrations which he is compelled to distribute throughout the entire length of the keyboard, the result of which is that the tone steps are not of equal length, nor is the same number of vibrations added or deducted to produce a half-step. It is to this difference in the intervals which assigns bold, martial music to the sharp keys, while plaintive, gentler strains are found better adapted

to the flat keys. Any pianist who will play the Star Spangled Banner, for instance, alternately in two sharps and four flats will, I think, readily comprehend this difference. We are thus enabled to accomplish far greater variety in music than would be attainable were these distances between notes uniform in extent.

There are minute vibrations which result in changing the molecular distances of fluids, forcing these asunder and causing evaporation. Noxious smells are created in a somewhat similar manner as well as perfumes, and the distinctive odors of animals and insects, by which they recognize and trace each other.

It is related of a dog, who had long been the constant companion of a horse, that, being separated from the latter animal for a time, accidentally crossed his track, and recognizing the scent, immediately followed and overtook his old friend.

The fox-hound, trained for hunting, will only follow the trail of the fox under any circumstances. I have been told by an old hunter that these animals have been known to follow a fox track in a line parallel to it, many rods away, with a favorable wind blowing toward them, for long distances. This delicate appreciation of distance by the strength of the scent is something of which humanity can have no adequate conception until we are educated up to the olfactory capacity of a fox-hound.

Vibratory sensation is capable of development. Practice in the microscopist gives him a power of vision which the uninitiated little dreams of. The piano tuner will discover an inharmonious element in a musical chord, which to another would be utterly unappreciable. The tea taster will detect a shade of flavor or value between samples which to the uneducated would be precisely similar. The physician readily recognizes the odors of diseases, in some instances, when these are sufficiently concentrated, but when the vibratory antagonism of the molecules of these have separated them until there is no more than the highest homœopathic attenuation in the atmosphere, there may still remain sufficient of both quantity and intensity to reproduce the parent disease.

I may be chimerical, but I believe the day will come in the not-distant future, when the ingenuity of man, through the patient plodding of some hard worker in the still rich fields of vibratory law, will mark the rates of perfumes and odors, and tabulate the vibrations

of disease germs as perfectly as we now count the vibrations of sound and light. How this may be accomplished I know not, it lies in the dark future; but the discovery and its application will be no more wonderful than the development of the spectroscope which tells us of the fires in the sun, which names the metals in a glowing fire a hundred millions of miles away in space, which names to us in language that any scientist in any land may read—in nature's own tongue—the fuel in glowing suns sixty times larger than our own, by analyzing to-day a ray of light that left its source years ago, and which tells us whether distant suns are traveling toward or retreating from our own solar system.

Look at the record of the past hundred years, and, noting the progress of science, ask yourself if this is to-day more distant than was the telegraph, the telephone, the induction coil, or the electric light, a century ago.

One curious thought in all this study of vibratory law obtrudes itself upon our attention and is worthy of note here. Nowhere has man invented a mechanical motion which is not more or less directly a reproduction of one of nature's own. Reciprocating motion? It is found in the molecular movements of particles. Rotary motions have their prototypes in winds, in the movements of vapors, in the orbits of the heavenly bodies and in their diurnal revolutions.

The swinging bough and the waving grain are repeated in the pendulum—the true type of all excursionary motion. The Leyden jar, the condenser, and the induction coil are thunder clouds in miniature, and the electric light is but a continuous stream of lightning, while the Geissler tube contains but a pocket sample of the Aurora Borealis, put up air-tight for home consumption.

Vibratory law lies at the very bottom of all vegetable and animal life. To it we are indebted for all that is beautiful, in art and in nature. It gives us all our magnetic and electrical action. It actuates our telegraphs and our telephones, the fire-alarm and the electric light. Our batteries would be powerless without it. Nay, more; without these minute movements, which pervade the entire universe, there would be neither heat, nor light, nor color. The stars would cease to shine and the sun would be a blank, invisible. The earth would refuse to move; all sound would cease; darkness and death and chaos would instantly succeed to the present beautiful creation.

REPORT ON EUROPEAN SEWERAGE SYSTEMS, WITH SPECIAL REFERENCE TO THE NEEDS OF THE CITY OF PHILADELPHIA.

By Rudolph Hering, C.E.

(Continued from page 376.)

VIII. Management and Cost.

The branch of the subject which is still left to be considered is one of no less importance than the design of the works. For, although well planned, these may yet fail to accomplish their object, if not properly executed or systematically inspected and cleaned. And likewise, good designs may become entirely impracticable by being too expensive for the locality.

I therefore made inquiries also into the management of the sewerage works in other cities and their cost, the general results of which are embodied in the following.

(*a*) Management.—Under this head it becomes necessary to speak of the municipal organization in general, pertaining to the sewerage works, then of the regular service for maintenance, and finally of the execution of new works. I shall first briefly glance at the departments having charge of the sewerage.

In London all public works of a general nature are conducted by the Metropolitan Board of Works, an elected body of 45 members. All main and intercepting sewers are designed, built and maintained under this board. Branch sewers are built and maintained by the engineers and surveyors of each of the various districts into which the metropolis is divided, but all plans must previously have been submitted to the Board for approval. The corps of the Metropolitan Board consists of 20 engineers and draughtsmen, and 174 inspectors, flushers and sluice keepers for the main drainage works.

In Paris all public works are under a Director General with a general office and a corps of twenty-six persons. Besides, there are six departments, each one having a chief engineer and a large corps of assistants. The one concerning us here, and which is charged with the water supply and sewerage, has a corps of 211 engineers, more than half of this number attending to the sewerage in its design, construction and maintenance. This branch is under a chief engineer, a con-

sulting engineer, a special engineer for construction and maintenance, and one for the disposal of the sewage.

In Berlin each department is headed by a chief engineer responsible to the municipal council. The design and construction of the new sewerage works are under a special and temporary department; their maintenance is under a permanent department.

In Vienna all public works are supervised by a Director General, each department being under a chief engineer. One department is charged with designing, constructing and maintaining the works connected with rivers, canals and sewerage.

Hamburg has its public works controlled by a Building Commission, consisting of three members of select council and ten private citizens, the chairman being salaried. The department for engineering has charge of streets, parks, bridges, sewers and surveys and is headed by a chief engineer, assisted by a large corps of engineers.

In Frankfort the sewers are designed, built and maintained by a special department, headed by a chief engineer.

In Liverpool the streets, sewers and the registration of property are in one department under a city engineer. He has a special corps for the design, construction and maintenance of the sewers and inspection of house drains.

In the smaller cities the city engineers usually have charge of all public works.

It will be seen from the organizations in the largest cities of Europe that with two exceptions, Berlin and London, the sewerage works in their design, construction and maintenance are in charge of "one" department. In Berlin the special department for design and construction wiil be continued only until the principal works are done, after which it will cease to exist. In London the enormous extent of the works makes it expedient to allow smaller sewers to be built and cleaned by district boards.

The practical importance of placing the care and maintenance of sewers in the same department, if this is permanent, in which they are designed and built, has been fully recognized in all of the cities. The responsibility regarding the continual good condition of the works naturally causes them to be designed and built in the best manner, so that they may be readily kept in good order.

In Philadelphia the responsibility is much divided. The sewers are all designed in one department, and are maintained by another. The

main sewers are built by the department designing them, and the branch sewers by the department maintaining them. The inlet-basins are designed by one department, built by another and cleaned by a third. The lines and grades for new work are given by a fourth body, the district surveyors who are elected by and are responsible to the people, while the three departments mentioned are responsible to councils.

However well the services of each body may be separately performed, it cannot be doubted that the absence of some controlling unit must necessarily permit of great incongruities in the final result.

A department which is required to keep the works in order and which has opportunity to observe their defects and incompleteness is in a better position to judge of how they should be designed than if it is required simply to design and not to maintain, nor even regularly to inspect them.

It can hardly be doubted, therefore, that we would be greatly benefitted if the responsibility with reference to our sewerage were more concentrated than it is. The works may be well built when transferred to the department charged with their maintenance, yet if their design is such that they are exceedingly difficult to keep clean it is not very surprising that with only ordinary care they should soon get into a permanently bad condition.

The other point to be observed in the European cities is that there are permanent and trained corps for regularly examining the sewers at fixed intervals, to ascertain whether they are in perfect order or not, and to thoroughly clean them, when necessary, in the most expedient manner. Flushing with the sewage itself is the most common method for cleaning, and requires a systematic regulation of the duties of the men and but a small additional expense for flaps, gates or penstocks. Only when flushing does not remove all obstacles is it necessary to use other means, which in some cities, as Frankfort and Hamburg, are even rarely required.

In Philadelphia this service is yet entirely wanting.

It has been abundantly proved that a system of sewers can never be satisfactory without this care. In Europe it has been found that if serious defects are to be avoided an occasional examination cannot be dispensed with, and in some of our American cities the regular maintenance of sewers is also beginning to receive attention.

According to the experience and practice elsewhere, it seems advisa-

ble, therefore, if sewers are to remain in a permanently good condition, that our city should institute an efficient system of regular inspection by competent men, together with a regular flushing or cleaning, as is customary in nearly all of the other large communities. Every sewer should be passed through at fixed and regular intervals, its condition reported, and when necessary, the deposits removed.

The last feature to be considered under this head is the execution of new work.

The main sewers in Philadelphia have lately been built in a manner which insures their perfect stability. The materials employed are good. The workmanship has also been greatly improved and may be considered satisfactory. The same cannot be said of the branch sewers. The materials used for them, although better than formerly, are not sufficiently good for the purpose, nor is the workmanship as careful as it should be. The inlets likewise are not well built, the materials are not always good, nor is the work done as carefully as their object demands.

With regard to the inspection of the building of new works a similar relation exists, partially explaining this result. During the last five years a regular and constant control has been exercised over the construction of main sewers. The branch sewers are inspected at rare intervals, between which the contractor is left to himself. The inlets and house connections are often not inspected until they are completed. A natural consequence is that the main sewers have been well built, and that the branch sewers, inlets and house connections are much inferior to what they should be.

All work is done by contract, the award being lately made to the lowest bidder with adequate real estate security, not with reference to the bidder's competency. Specifications are drawn in a manner to cover all contingencies. They require a bid per lineal foot, no matter what extra quantities of material or work may be required, thus throwing all risks upon the contractor.

The European methods of executing sewerage work I found on the average to be very different from these, and impressed me as being much superior. The materials are uniformly of the best for all parts of the work. They are selected to give strength, to give a regular and smooth interior surface and to make the sewer water-tight, as already mentioned. No less care is displayed in the workmanship throughout.

The inspection of work in progress is very efficient, there being at

least one inspector for each piece of work, however small, such as inlets, house connections and repairs. They are required to certify to the faithful performance of any contract work before payment is made therefor.

In a few cities, as Berlin, the sewers are built by day's work under immediate direction of department officers. In most of them, however, they are built by contract. The specifications, then, are concise and strict. The sewers are bid for per running foot, yard or metre, but for large work a schedule of fixed prices, established by the city, is always attached, for adjusting a variation of quantities from original estimates. Contracts are generally awarded to none but those who are known to be most competent contractors.

As the advantages gained in Europe for the ultimate character of the work by this general superiority of materials, workmanship and inspection, are so marked, I cannot too much urge that greater attention be paid to this matter in our city.

In summing up the points with regard to the execution of new work, I would offer the following recommendations: First, that better materials be used, especially for branch sewers and appendages, as already indicated in detail. Secondly, that the work be done with more reference to giving the interior a smooth surface, and to making the sewers water-tight, all of which again refers more particularly to the branch sewers, and of which the value has also been previously set forth. Thirdly, that contracts and specifications be drawn for every piece of work as comprehensively, to cover every expected feature, as done heretofore. Fourthly, that no piece of work for the city be done without constant inspection during construction, and that no payments be made without a certificate that it has been so inspected and is known to be properly executed in all of its parts.

(*b*) Cost.—Finally, it is necessary to say a few words on the subject of cost, and to inquire into the effect which the changes I have recommended would have on this very important factor.

I shall first inquire into the expenditures of other cities for both construction and maintenance, in order to see what part of the municipal expenses may reasonably be allowed for this branch of public works. A direct comparison can of course not be made, as different conditions are present in each; yet an approximate comparison will suffice.

On the whole, I found that the average expense per foot of sewer

was about the same as in Philadelphia, not considering that the price of our labor is somewhat higher. The average cost of our sewers since consolidation has been $5.21 per foot, including mains and branches, and excluding street inlet-basins, whereas in Europe the general average under similar conditions, for the total works is nearly $6.00 per foot.

Regarding the annual cost of maintenance, our expenses have been as follows, including repairs and excluding the cleaning of inlet-basins, which is done under the Board of Health in connection with the street cleaning:

1874,	7·0 cents per foot.	1878,	12·0 cents per foot.
1875,	12·7 " " "	1879,	11·0 " " "
1876,	11·8 " " "	1880,	3·6 " " "
1877,	13·4 " " "	1881,	2·8 " " "

In Europe the entire annual expense for maintenance in all of the largest drained cities, excluding the pumping of sewage, is as follows, the amounts varying imperceptibly in different years. And it must be added that in these cities the sewers are kept very clean, so that walking through some of them was not found at all disagreeable.*

Paris,	13 cents per foot.	Hamburg,	$3\frac{1}{2}$ cents per foot.
Vienna,	9 " "	Frankfort,	$3\frac{1}{2}$ " "
London,	6 " "	Liverpool,	3 " "
Berlin,	$4\frac{1}{3}$ " "		

To properly compare these figures with ours, it is necessary to state that while in Europe the proportion of the above amounts spent for repairs is insignificant, in Philadelphia it averages more than three-fourths of the entire expenditure for maintenance. The amount used for cleaning alone is difficult to estimate, but it will hardly be more than two cents per foot. While this fact shows the effect of inferior construction, it also shows that we devote much less money to cleaning than in Europe. And if we couple with this the fact that our sewers, as previously indicated, are exceedingly difficult, and therefore, comparatively costly to clean, their present condition, although better than formerly, is, I think, rationally explained.

It, therefore, appears, generally speaking, that in Europe about the

*In Paris it is common that strangers, ladies included, make trips through the sewer. In Hamburg, the Crown Prince of Germany a few years ago took a trip of several miles through the largest sewer (ten feet in diameter).

same amount is paid for the construction of sewers, but a much greater amount for their maintenance, *i. e.*, cleaning.

In order that our own works may be of a similar standard of efficiency it, therefore, ought not to require the expenditure of more money per foot for new works, except, perhaps a slight increase for the difference of wages; but it would necessitate a greater sum for cleaning sewers, the expenditure of which cannot possibly be done without, if sewers are to remain in a sanitary condition, as I endeavored to show at another place.

Among the European cities just mentioned, London and Vienna mostly resemble Philadelphia, as far as the design of the sewers is concerned, and the sum there required for cleaning will be a guide as to what might be necessary here. London spends six cents per foot per year, but has abundant flushing facilities. Vienna spends nine cents per foot per year, and has no such facilities, the sewers at present being cleaned by manual labor, as here. Applied to Philadelphia these figures would represent \$60,000 and \$90,000 per year respectively, whereas \$92,367 per year is the average yearly cost of maintenance in our city for the last eight years, including cleaning and repairs of sewers and excluding the cleaning of inlets.

With greater care in the design and construction, as has been suggested, our repairs to sewers, which make up the greatest part of that amount, would soon diminish and the proportion required for proper cleaning could be correspondingly increased, so that the total sum would not become greater than heretofore, but possibly even less, as shown.

As these are the conclusions arrived at from a general point of view, it remains to see whether they will also hold good when considered more specially with regard to the separate recommendations contained in the previous parts.

Passing over the house drainage, which is paid for by the owners, to the street-inlets, the suggestions there contained will not increase the cost beyond what would be necessary to build the present designs with the necessary care. It might even be diminished, as far as they could be more sparingly put in at the highest and lowest points of the drainage areas, and also as far as their design can be simplified. In the case where two inlets were recommended at a corner instead of one, the increased expenditure must be charged to the avoidance of the

objectionable features at a crossing, occassioned by a single inlet, and be considered as a local matter only.

Further, in discussing the sewers, it was noted that by changing their form from a circular to an egg-shape, a decrease in the width of excavation is obtained, and in many cases, where a small brick sewer is built three feet in diameter, for the only reason that it may be passed through by workmen, the egg-shape also gives a decrease in the amount of brick-work, both of which tend to reduce the cost below that of the present sewers.

When next considering the proper sizes it was concluded that pipe sewers should be laid wherever practicable in place of building three feet sewers, which also, besides making a superior sewer, somewhat reduces its cost. It was further concluded by conforming to the methods elsewhere adopted in proportioning the sewers with reference to the rainfall, that our largest sewers can be very greatly reduced in size without making them less efficient. In the special case cited, *i. e.*, the Mill creek sewer, it was concluded that a twelve foot sewer would answer fully the place of the twenty foot sewer. In calculating the difference of cost this represents it will be found to be no less than $10 per foot, or over $50,000 per mile.

A similar proportion of saving might be effected in the main sewers in all of the larger drainage areas in our city which are yet to be built.

A corroboration of this feature is given by an eminent American engineer,* who arrives at similar conclusions from his own experience with the sewers of Brooklyn.

By adopting a more rational system of proportioning sewers, therefore, and one which is endorsed by the best authorities, a considerable saving of expense can be effected, which I feel confident will fully compensate the additional expenses which should be incurred to make our system more perfect, and which I shall now mention.

The proper and careful construction of junctions, connections, etc., of sewers, were found to be of greater importance in maintaining them in a good condition than commonly supposed, and a slightly greater expenditure in making ours more perfect is well placed; for instance, by building tongues at junctions, by using cast-cement or terra-cotta blocks for house connections, and by other slight but telling improve-

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*J. W. Adams, Sewers for Populous Districts, 1880.

ments. Similarly the appendages to the sewers may profitably receive greater care, the most important in this respect being the gradual introduction of flushing gates, by which the sewage is penned back for a short time, and on being suddenly released flushes the sewer. The expense of these gates, however, is itself more than repaid by the saving effected in the employment of hand labor for cleaning the sewers. Likewise will the expense of having catch-pans or basins in man-holes, to prevent street-dirt from dropping into the sewers, be repaid, for the same reason that the present catch-basins at the street-inlets compensate for their cost.

The recommendations made with regard to the details of alignment embody features which again decrease the expense, besides making the sewers more efficient, such as the early concentration of sewage into mains, and as the placing of small sewers near the gutters of wide streets.

A not inconsiderable saving can also be obtained by adopting the separate system in parts of Germantown and Chestnut Hill, in building sewers for sewage alone and allowing the rain-water either to flow over the surface or in shallow channels to the nearest creek.

It is now in place to indicate how much the cost would be affected by a better execution and management of the works. Without positive figures, of course, no positive results can be obtained, and I can only speak of this point in a very general way.

The greater expense caused by a better class of material and a more careful workmanship will be slightly decreased by the feature that the greater degree of smoothness, by increasing the velocity, admits of a smaller sized sewer. Pipe sewers, up to 15 inches diameter, cost less than three feet brick sewers, both being equally well built.

Again, the greater expense of a more thorough inspection of the building of our works will be compensated by the superior grade of execution attained thereby, not only by causing a more efficient sewer in its operation, but also by preventing the large number of breaks, the repairs of which have yearly required an extraordinarily large sum of money. But even if better sewers would be more costly, their sanitary importance, I trust, would fully justify a small additional expense.

Also, a more concentrated organization for our sewerage works, as suggested in place of the present divided responsibility, would tend rather to decrease than to increase the expense of supervision, design

and maintenance, if public work and private work are to be judged in this respect on a similar basis. It appears, therefore, that a better execution and management of the works could not greatly raise the present total expense for this purpose.

Anticipating that the condition of our works would demand a large expenditure of money to bring them up to a sanitary standard, the subject of cost appeared to me an important one for this city. Therefore, while abroad, I gave very special attention to all directions in which a saving might justly be effected. And I am now gratified to say that from these conclusions, as far as they can be drawn from general inquiry, there is every indication that the changes which I have seen proper to recommend, to establish a good system, such as is common in the large cities of Europe, will not, on the whole, require more money than the average amounts we have spent for sewerage during the last decennium. The greater expense necessary in some directions to make the works better, both from a constructive and a sanitary point of view, will be balanced by a less expense in other directions. To do the latter without the former, however, should be deprecated to the utmost degree, because the first and foremost object of a system of sewers is a *sanitary* one, and this should not be sacrificed even if a saving of money could be effected thereby.

Although the cost of better works would apparently necessitate no greater expenditure than heretofore, the cost of repairing and altering improper ones will be additional. But this expense cannot be done away with under any circumstances, if the sewers are to be put into a proper condition. A few thousand dollars, however, spent judiciously every year, would soon relieve the city of the effects of the most objectionable defects in our sewers.

Before closing this part, a few words must be added with regard to the cost of the intercepting sewers recommended for the future.

An early study into the alignment of an ultimate system, and its early establishment, will enable sewers which later must form essential parts to it, to be given such positions and elevations which will be suitable for the future, besides answering their present purpose.

The Manayunk sewer, which is to contribute towards preserving the purity of the Schuylkill drinking-water, requires a diameter of not over five feet, its expense will not be over $750,000. The urgency for this sewer depends on the degree of pollution of the Schuylkill by the Manayunk sewage.

The sewer proposed to intercept the south-western slope of Germantown and to carry the sewage to the West Cohocksink basin requires a diameter of less than four feet, and would cost for a length of four miles about $125,000, a large part of which would be covered by the usual assessment on properties. The urgency of this sewer will depend on the necessity for preserving the purity of the Wissahickon creek.

The northeastern slope of Germantown is now drained into the Wingohocking creek, which subsequently discharges into the Frankford creek. The intercepting sewer suggested to prevent the Germantown sewage from polluting the Frankford creek, which can never be sewered, and should, therefore, always be kept as pure as possible, begins at Wingohocking creek where the North Pennsylvania Railroad crosses it, and can discharge temporarily into Hart creek sewer. Its length is about one and three-quarter miles, the diameter would be about five feet, and its cost about $90,000. The necessity for this branch of the general system of interception would arise, when the pollution of the Wingohocking creek and Frankford creek by the Germantown sewage is considered objectionable.

The remaining intercepting sewer, which may seem necessary at no distant day, is the one which prevents the sewage from flowing into the Delaware river docks between Kensington and the old Navy Yard. An approximate estimate of its cost, however, can not be made without a more detailed study than I have given it.

IX. Recapitulation of General Conclusions.

I shall now conclude my report by reviewing the main points which, from my inspection and study, I believe to be of most importance as far as the needs of Philadelphia are concerned.

In order to get as complete an understanding of the subject as possible, I visited every city in England and on the Continent where any pretence was made of having a good or instructive system. Nearly all of the cities showed works greatly superior to our own. The designs were, as a rule, carefully conceived in accordance with engineering and sanitary principles. The construction, too, received more care, in the selection of materials, in the workmanship, and in the inspection. The maintenance of sewers, to which as yet but little attention is given in this country, except in a few cities in New England, is carried on in every city by a well-trained corps, which

regularly flushes and cleans all the sewers at frequent and fixed intervals, so that I did not find an objectionable condition in any system or part of one claimed to be good, even when selecting my own points where to enter and examine them.

To render the Philadelphia sewerage works equally efficient, from a sanitary and economical point of view, it will be necessary to alter and improve the designs and the construction, and to institute a regular system of flushing. In what special directions these improvements should be made I have indicated under the corresponding heads. I shall simply restate them as briefly as possible.

In view of the several systems of city sewerage which are advocated at present, and of each of which I examined the best examples, my conclusions are that different parts of the city will be best served by different systems. For the greatest portion of our city the one which is or will be closely built up during the present generation, the so-called "combined" system, leading sewage and rain-water into the same channels, is the preferable one. For suburban districts, which are not likely to become densely populated, the so-called "separate" system, by which the sewage is led into sewers and the rain-water either into a few special and shallow channels or entirely over the surface, is to be preferred, because it is as efficient for such localities and much more economical. Should any of these suburbs ever become closely built up, it also in no way prevents the gradual addition of subterraneous rain-water channels as needed from time to time, thus forming a complete separate system.

Under the head of house sewerage, it is suggested that cesspools or wells should be deprecated and as much as possible abolished. Municipal regulations regarding the house drainage should be adopted, following in this not only many European but also some American cities.

The parts of the system receiving and discharging the street water into the sewers—namely, the "inlets"—should be built so as to insure a water-tight basin and an effectual trap. They should be placed, where possible, above the sidewalk crossing instead of at the corners, in order to avoid the objectionable gutters—a custom which is almost universal in Europe. The "necks" should be of vitrified pipe, instead of two-foot brick sewers, in order to avoid deposits and retention of foul matter in them. Further, inlets should be placed as sparingly as possible at the highest and lowest parts of drainage areas, where they are seldom justified.

The sewers themselves were next examined into and the following conclusions arrived at: Regarding the proper shape to be given to them, it was shown theoretically and by the long experience in Europe that none but an egg-shape will conform to the requirements of a sewer of the combined system, and that our custom of building them circular is one of the main causes of our troubles. For intercepting and pipe sewers only the circular shape is the best.

Regarding the size of the sewers, it was found that essential improvements could also here be made. In the absence of observations showing the effect of storm-water in our sewers, the obtaining of which is urged, the experience from many European cities was collected, examined and compared with American experience, and the results applied to our own conditions. This revealed the fact that if our small sewers are correctly proportioned, the largest ones are entirely too large; and if the latter have a proper size, the smaller ones are too small. The first case, however, is nearly the true one, regarding storm-water removal. That the reduction of size obtained thereby is a matter of great economy will be self-evident, and that it is also one of sanitary benefit, in the better conveyance of the sewage itself, is a point acknowledged by all sewage engineers in Europe, and has recently, by an extreme case, also been shown in Memphis, Tenn., in the system designed by Col. Waring. Quite contrary to a common opinion that our sewers are too small, there is no doubt that an essential source of trouble is caused by their often being too large. The superiority of well-laid pipe sewers over brick sewers is likewise alluded to.

The grades are next considered and the proper limits indicated. The practical importance and economy of distinguishing between dry-weather and storm-water flow near outlets into tidal rivers is also shown.

Finally, it is urged to give more attention to the construction of branch sewers, after mentioning the great superiority in the materials and workmanship employed for this purpose in Europe and the advantages which accrue therefrom. Besides giving sewers more stability, the walls should be made water-tight and the interior surface as smooth as possible, to prevent retention of filth. When it becomes necessary to alter the most objectionable of the three-feet sewers, it will generally suffice simply to re-form the invert with concrete, instead of rebuilding the entire cross-section.

A more careful consideration is then recommended to be given to

the proper designs for sewer junctions, house connections, storm-water overflows and sewer outfalls into the river, with a view of avoiding any retention of matter by eddies and backwater—points which in Europe have received much greater attention, and the importance of which is fully set forth.

The various appendages to sewers to facilitate their inspection, their ventilation and flushing are then examined, the most efficient plans customary in Europe indicated, and the special features emphasized which are applicable to and advisable for our own conditions. It is found that the only effectual and economical mode of ventilating sewers, after many trials and long experience, is by gratings in the manholes placed in the middle of the street, and by soil-pipes when they are built of iron with leaded joints and carried above the roof. It is further found that flushing with sewage itself, as practiced in nearly all large cities of Europe, is not only effectual in removing all ordinary deposits, but it is the most economical method.

In order to attain these benefits, however, it is necessary to improve several conditions simultaneously. A regular inspection of our sewers becomes impracticable without a good ventilation for them. The latter, when obtained through openings into the streets, is often objectionable, unless the sewers are regularly flushed and built with a smooth surface and otherwise in accordance with the principles previously stated. Flushing, finally, cannot be effectual without appliances therefor and a systematic service.

Several points are then given with regard to the alignment of sewerage systems. Valley line sewers were used wherever no difficulty was experienced in having a natural outfall. Intercepting sewers were used to prevent an undue accumulation of rain-water at the foot of slopes, to prevent sewage or rain-water from flooding low districts, and the former from flowing into the rivers and docks in front of a city. Attention is called to the fact that early concentration of sewage into a few larger channels is more economical than to collect it more uniformly from the area.

An inquiry into the ultimate disposal of the Philadelphia sewage revealed the fact that purification is not necessary, and that the Delaware river is sufficiently large to receive it without the danger of causing pollution. It will become necessary, however, to prevent a deposit of filth and silt along the wharves, by carrying the sewage either into

the channel by a few submerged conduits, or by an intercepting sewer to a point below the city.

I have then proposed a system of intercepting sewers, which, in its general features, seems to answer present and all future requirements, and which conforms to the principles tested and practiced in Europe. It has also the advantage that small portions can be built to relieve certain sections from time to time as required, and of being uniform in its entirety and making a complete and economical system in the end. The sewers which would be among the first to require construction are those preventing a pollution of the Schuylkill river from the Manayunk sewage, the Wissahickon and Tacony creeks from the Germantown sewage, and the docks along the Delaware river from the sewage of the older part of the city. A close study into the adoption of some ultimate system is urged, so that works hereafter built may conform thereto and future rebuilding become unnecessary.

The question of the management of sewerage works is then entered into, and after indicating the organizations for this purpose in all of the large European cities, it is found that the designs, the building and maintaining of the works, are placed under one head, while in our city the responsibility is divided among four distinct bodies. A greater concentration could not be otherwise than beneficial here, as it is in Europe.

It is then recommended to gradually institute a system of regular flushing, the best and most economical means by which a system of sewers can be kept in a sanitary condition. Also, that no part of the work be done without a constant and competent inspection.

The last part of the report contains an inquiry into the effect which the foregoing recommendations will have upon the cost of the works. From a general comparison between expenses in foreign cities and our own, it is found that we spend nearly as much for new works per running foot under similar conditions. In comparing the cost of maintenance, it is found that the city whose sewers most resemble our own—Vienna—spends nearly the same amount per foot, and that London, which stands next in resemblance, spends about two-thirds of our amount, but has complete flushing facilities. From this general comparison, therefore, it would seem that the sewerage works in our city, in order to be efficient, should not require much more money, if any, than heretofore. And this is confirmed by a detailed inquiry.

With regard to new works, it is stated that an increase of expenditure

would be very desirable and beneficial in the direction of improving the designs of junctions, house connections and manholes, and in bettering the standard of the materials and workmanship, particularly for branch sewers and appendages. On the other hand, it is found that a relative decrease of expenditure can be obtained by building egg-shaped and pipe sewers, in place of three-feet circular branch sewers, where the capacity admits of it. Further, a very large saving of expense is gained by a more rational proportioning of the sizes of sewers, and by adopting the separate system for certain outlying districts. New works, therefore, when designed and built as recommended, need not, on the whole, require more money, apparently, than when built according to present customs, the exact relation to be determined only by a detailed and local estimate. The increased cost for more thorough inspection of new works will be fully compensated by a decreased cost of repairs. In Europe the necessary repairs to sewers are quite insignificant, and in our own city the sewers which had a constant inspection during their construction have so far cost nothing for repairs.

The maintenance of sewers requires the additional expense of flushing gates and penstocks, but the saving of hand-labor effected by them in removing obstructions much more than pays for their cost. The proportion of our average yearly expense for maintenance devoted to repairing breaks or defective sewers, is estimated to be over three-fourths of the entire amount. When the sewers are better designed and built under inspection the repairs must become less and less. If the amount of money thus gradually saved is devoted to a more thorough cleaning and flushing, the sanitnry condition can be improved without greater expense than needed heretofore. And if the comparison between Philadelphia, London and Vienna is taken as a guide, the same average cost of maintenance which has been required during the last eight years would in future be sufficient to keep our sewers as clean as those in Europe.

When it is finally considered that a greater concentration of authority could not greatly increase department expenses, if at all, it seems to be clearly indicated that also a detailed inquiry into the changes recommended leads to the same conclusion which was drawn from a general comparison with European expenditures.

Before closing I desire to state that during my visit to the various towns I was impressed with the fact that the design and maintenance

of city sewerage, if it is to be a sanitary work, requires more skill and attention than is usually given to it in our own country, or even thought necessary. And herein lies a fundamental reason why so many works are in an imperfect condition. The best sewered towns in Europe were designed and managed by specialists in this branch of public works. Nothing short of a careful study, therefore, could reveal the features which were best adapted to the requirements of this city.

With the hope that this report may fully cover the required points and may contribute towards the improvement of an important branch of the public works of our city, it is respectfully submitted.

Excess of Labor in Schools.—In a large establishment, containing about 600 children, half girls and half boys, the girls were found to accomplish an amount of labor greater than that of the boys. At each inspection it was observed, with surprise, that they were more alert and better developed; and yet the girls were in school only eighteen hours per week, that is to say upon alternate days, while the boys had thirty-six hours per week. Afterwards, when the boys were submitted to the same rules as the girls, their work was much more satisfactory.—*Les Mondes* C.

New Cometary Theory.—Prof. C. Schwedoff, of the University of Odessa, regards the tails of comets as simply luminous phenomena. The nucleus of the comet, in traversing the æthereal medium in the manner of a projectile would produce at each instant, by the compression of the æther, a luminous wave. The trajectory traversed by the nucleus should then be considered as the geometrical locus of a centre of movable undulation, and the partial waves, emanating successively from the different points of this trajectory, would give, on superposition, a resultant wave which would be the cometary form itself. Schwedoff calculates the comparatively simple case of the section of the wave by the orbital plane, that is to say, the form of the comet for an observer placed at an infinite distance upon the normal of the plane. He thence deduces the possible existence of two types of tails. His theory reduces the study of cometary forms to the discussion of a mathematical formula, and thus merits the attention of astronomical geometricians. Observation alone can decide whether it has a sufficient physical foundation.—*Ciel et Terre*, June 1, 1882. C.

Explosion of Carbonic Acid.—L. Pfaundler placed a sealed glass tube, which was about two-thirds full of liquid carbonic acid in a bath of carbonic acid and ether, which had been reduced to a temperature below —100° (—148°F.), in order to obtain crystallized carbonic acid. Beautiful, transparent, strongly refracting crystals soon appeared, which completely filled the submerged portion of the tube, while a layer of fluid carbonic acid floated over them. After a few minutes the upper end of the tube, which was exposed to the air, suddenly exploded with a loud report. The same tube had previously been often exposed to a temperature of more than 31° (55·8°F.) It is possible that the glass, at this low temperature, became so brittle that it could not bear the steam pressure of the still fluid portion of the carbonic acid and the influence of the temperature of the air. But it seems more likely that the solid carbonic acid burst the tube in consequence of its thermal expansion.—*Ann. der Phys. und Chem.*, 1882, p. 175. C.

The Figure of Comets.—M. Faye thinks that the combined influences of solar attraction, which tends to decompose bodies of small mass and great volume, and of solar repulsion, which begins to act on the evaporable portion of the mass which is withdrawn from all pressure and submitted to an increasing heat, are sufficient to explain cometary phenomena, without resorting to the hypothesis of an electric or magnetic repulsion. In the irresolvable nebulæ, and the manner in which they are distributed in space, he finds evidence of the repulsive action which the stars exercise over the extremely tenuous matter by which they are surrounded. The light of the nebulæ appears to him to be of exactly the same nature as that of comets. He can find no reason for attributing a cosmic agency to the electric forces which we observe upon the earth. It is true that the least chemical action, the least friction, the least contact of two bodies, sets these forces in play; but by the very nature of polar forces they soon become mutually destructive. If the globe is an immense reservoir of electricity the electricity is neutral, and it is only occasionally that the existence of the forces is perceived. It requires the genius of engineers to separate them, to conduct them to a distance, and to force them to execute their admirable works by their recombination. Beyond the globe all this disappears. The simple incandescence of the sun is sufficient to explain the phenomena of repulsion which are indicated by the gigantic tails of comets.—*Comptes Rendus*, xcv, 427. C.

Curious Observation of Comet Wells.—On the 10th of April, 1882, Prof. Zona determined the position of this comet; but at the end of the observation, he noticed that the light of the tail changed while he was looking at it. He paid no attention to this phenomenon because the sky was cloudy and his eye fatigued. On the 14th he made a similar observation, but he attributed it to an atmospheric cause, the sky being not yet entirely clear. On the 17th the phenomenon returned with more marked intensity, the sky being cloudless. The Professor called his assistant and asked him to look at the comet's tail. After some minutes the assistant said: "It seems to me that the light of the tail gradually diminishes, as if the nucleus was attracting it, and then increases, as if it was going out from the nucleus." Prof. Zona then looked more attentively, and saw that the tail had a steady but very feeble light during eight or ten seconds. Then, for about a second, the tail had luminous pulsations, after which the period of calm returned. The phenomenon reminded him of the scintillation of the glow-worm and the movements of the aurora.—*Les Mondes*, cited in *L'Astronomie*, i, 272. C.

Synchronism of Electric and Optic Phenomena.—E. Bichat and R. Blondlot have studied the rotation of the plane of polarization in a transparent body, under the action of the discharging current of a Leyden jar. The transparent body was placed between a polarizer and an analyzer, in a coil with long and fine wire, which was connected with the armatures of a battery. In the circuit was interposed an exciter, which allowed a discharge to be produced when the difference of potential was sufficient. At the moment of each discharge the eye which was placed before the analyzer noticed a vivid reappearance of light, which showed that the plane of polarization had been changed. A mirror, turning about a vertical axis, was then placed before the optic apparatus. The polarizer was provided with a slit, likewise vertical, through which the image in the mirror was observed by means of a telescope. An arrangement was made for producing the spark at the moment when the mirror occupied such a position that the image of the slit was visible in the telescope. Two systems of bands were thus observed: one due to the light of the spark, the other to the polarizing apparatus. The electric and optical phenomena were absolutely simultaneous, or, if there was any difference, it must have been less than $\frac{1}{300000}$ of a second.—*Comptes Rendus*, xciv, 1590. C.

Subsidy to Pasteur.—The French minister of Agriculture has lately placed at the disposal of M. Pasteur a new sum of 50,000fr. ($10,000), in order to continue his admirable investigations upon the contagious diseases of animals. The government had already granted to the illustrious savant, for the same object, 50,000fr. in 1880 and 40,000 in 1881. The minister consulted a special committee who, in view of the brilliant success obtained by Pasteur in his previous investigations, unanimously recommended a renewal of the grant.—*Les Mondes*, Sept. 9, 1882. C.

Solar Cannon of the Palais Royal.—The little cannon of the Palais Royal, in Paris, which automatically notes the hour of noon, dates from a greater antiquity than is generally known. It thundered during the commune, under the empire, during the days of '48, under Louis Philippe, under the Restoration, during the wars of the Grande Armée, during the guillotines of the Reign of Terror, on the day when Camille Desmoulins harangued the people, under Louis XVI, under Louis XV. In his charming "Journey from Paris to St. Cloud, by Land and by Sea," published in 1751, Néel makes his young tourist regulate his watch by it. The pillar on which it is fixed stands at the point where, in 1641, a year before his death, Cardinal Richelieu established a bound between the manors of St. Honoré and of the Archbishopric. —*L'Astromomie*, i, 241. C.

Improvement of Marshes.—In the province of Venice there are still extensive tracts of marsh, especially in the territory comprised between the Tagliamento and the Livenza, and between the latter and the Piave, in the two districts of Portogruaro and of San Dona. These two districts include 38,000 hectares (146·57 sq. m.), besides many tracts already under cultivation, which suffer greatly from obstructions to the free flow of water. In these districts there are improvements, which have been executed by intelligent occupants, who draw large profits from them, although they have sustained the entire burden at their own expense; but they are true oases in the midst of broad filthy marshes, and serve as an eloquent proof of the great advantages which might be derived from the redemption of the fertile virgin soil. The Italian government has offered subsidies and other measures of protection and encouragement, in the hope of extending these improvements for hygienic as well as agricultural purposes.—*Il Politechnico,* xxx, 458.

Water-Spouts at Etretat.—Leon Lalanne, in a letter to M. Faye, records his recollections of an interesting phenomenon which he observed on a September morning, in 1851. Eleven water-spouts were formed in less than a quarter of an hour, before the eyes of spectators who were surprised and considerably disturbed at the consequences of the phenomenon, which was driven directly before them. Finally, without lightning, without thunder-claps, but in the midst of a gust of wind which culminated in a tempest, one or two of these water-spouts were seen to break in a deluging rain against the rocks which jutted from the western part of the beach. The spectators were soon overwhelmed with torrents of rain, accompanied by heavy squalls of wind, but without any other evil result than that of being thoroughly drenched. The occasion was remarkable for the large number of simultaneous water-spouts, and M. Faye regards it as strongly confirmatory of his whirlwind theory.—*Comptes Rendus*, xcv, 430. C.

Influence of a Polished Specular on Actinic Reflection.—M. de Chardonnet has photographed, with instruments of quartz and of Iceland spar, the spectrum of rays reflected from a variety of substances. By prolonging the exposures sufficiently he has been able to assure himself that there is no absolute eclectic absorption. He tried in succession: white enamel, black enamel, uranium glass, rough hematite, polished hematite, diamond, compressed carbon, both rough and polished vermillion, gold, lead, nickel, Arcet's alloy, copper, polished steel, rough steel, Prussian blue, green leaves, telescope metal, and mercury. Silver would seem to be an exception to the general rule, because it becomes transparent for the second half of the ultra violet spectrum; but on prolonging the exposure this region appears with all its details. Among liquids, he tried distilled water, solutions of fuchsine, of acetosulphate of quinine, of ammoniacal sulphate of copper, of bichromate of potash, milk, ink, alcohol, ether, benzine, olive oil, which all gave complete spectra. From his experiments he deduces the following laws. Every surface reflects, in variable proportions, each of the radiations of the spectrum. The reflecting power of a liquid is independent of the substances which it holds in solution or in suspension. The polished specular serves to increase the total quantity of the reflected radiations, while the relative intensity of the different regions of the spectrum, or the actinic color of the body under consideration, depends on the material employed.—*Comptes Rendus*, xcv, 449.

Franklin Institute.

Hall of the Institute, November 15, 1882.

The meeting was called to order at the usual hour, with the President, Mr. Wm. P. Tatham, in the chair.

There were present 149 members and 19 visitors.

The minutes of the last meeting were read and approved.

The Actuary submitted the minutes of the Board of Managers and reported that at the stated meeting held Wednesday, November 8th, 16 persons had been elected members of the Institute.

The Special Committees on Prevention of Fires in Theatres and on Memorial to Mr. Briggs reported progress and were continued.

Mr. Wm. B. LeVan read the concluding portion of a paper on "Steam Economy," which appears in the Journal for December.

Mr. J. Snowden Bell inquired the author's experience in the use of heated air.

Mr. LeVan replied that when introduced above the grate he found it to be of decided advantage if sufficiently hot, *i. e.*, above 800°.

Mr. Hector Orr, referring to the author's statement of the small percentage of the thermal effect of the fuel which was utilized in the steam engine, claimed that this wastefulness was to be charged to the use of solid fuel. He advocated the substitution of gaseous fuel.

Mr. Wm. E. Lockwood asked the author's experience as to the economy of using high pressures.

Mr. LeVan replied that pressures of 200 pounds had been worked quite successfully. Higher pressures had not been found so satisfactory, mainly, he thought, because of the want of the necessary experience. He believed that the time was not far distant when the use of high pressures would be the common practice, and when 200 pounds would be considered an ordinary pressure.

Professor Wm. D. Marks made the criticism that steam economy, as the author had put it, might not necessarily imply economy in dollars and cents; that the interest and other charges in maintaining an expensive and complicated plant might more than offset other advantages.

Mr. LeVan replied that he proposed to economize by subdividing the power, using a number of small engines in place of one or more large ones. In answer to questions he further added that with respect

to engineers' wages, he believed that this item would not be greater, or that it might even be less. He did not think that there would be any increased hazard in the use of very high pressures. He believed that where there was greater risk, this was always compensated by the exercise of greater care.

In the absence of the author, a paper on the "Abstraction of Heat by Mechanical Energy," by Mr. John Rowbotham, was, on motion of Mr. A. B. Burk, read by title.

The following are the more prominent subjects mentioned in the Secretary's report:

Several forms of improved Testing Machines, designed by Mr. Tinius Olsen, were described, including one for scientific investigation made for the Rensselaer Polytechnic Institute of Troy, N. Y., capable of applying continuous strains of every description to test pieces, as well as intermittent strains. A Spark Arrester for Locomotives, invented by Mr. Rufus Hill, Master Mechanic of the Camden and Atlantic Railroad Co., and which was said to have shown itself to be well adapted for its intended uses, was shown and described. A number of views showing details of Mr. Pohl's Differential Car Starter were exhibited and described. The following inventions were also exhibited: A Friction Drive Chain, made by the Ewart Manufacturing Co. of Chicago, in which the links of malleable iron are detachable, each link having projections forming wedges which engage in a continuous groove in the pulley-wheels. A Safety Belt Mounter, made by R. P. Ashley, of Camden, N. J., after a pattern long used with success in England, and which puts taut belts on running pulleys without delay or danger. A specimen of Car Axle Brass of "Deoxydized Bronze," made by the Philadelphia Smelting Co., a very dense and homogeneous metal, with very high polish and regular surface, free from pits or blow-holes. Clapp's Circulating Drop Tube for Steam Boilers, made by the Clapp & Jones Manufacturing Co., Seneca Falls, N. Y. The tube depends from the crown sheet into the combustion chamber. Three slips of iron arranged triangularly form a partition to assist the circulation. These slips are punched with lips to assist in preventing the entanglement of water with the steam.

Dr. B. A. Watson's Lever Excision Saw, a surgeon's saw, designed to take the place of the chain saw, and claimed to be simpler and more rapid in its action; A. H. Reid's Lightning Brace, for light boring and screw driving. The power is applied at the top, enabling consid-

erable force to be applied. It may be used either by running the bit both back and forward, or by turning the bit one way only, as is necessary to drive a screw or bore a hole with an auger bit. This is done by means of a divided head, which acts as a fast and loose pulley, there being no ratchet. A series of very minute files for jeweler's use, made by Mr. Wm. Myers, of Philadelphia. A small indicator, made by the Crosby Steam Gauge & Valve Co., of Boston, and designed especially for indicating locomotives and high speed engines. A new plastic material, invented by Mr. Edward Weston, of Newark, N. J., and intended as a substitute for celluloid and for other uses. Specimens of the material, and of carbon filaments for incandescent electric lamps, made from it, were shown. The latter possessed a remarkable metallic lustre.

Dr. Bruno Terne next described a representative collection of products manufactured from animal bones, which were presented to the Institute by the manufacturers, Messrs. Baugh & Sons, of Philadelphia.

The President, Mr. Wm. P. Tatham, after inviting Vice President Frederick Graff to the chair, then described the principles of construction and mode of using the dynamometer, which he had at length succeeded in perfecting, at the cost of much study and time. In presenting the machine to the Institute he stated that the Institute was under obligations to the Isaac P. Morris Co., and Messrs. Fairbanks & Co. for having respectively furnished the pulleys, shafts, bearings, and cast iron frames and the scale work, without charge. He added that he desired a critical investigation of the machine by the Institute through a committee or otherwise, and hoped, if it met with approval, that the Institute would adopt it, and let it be known as the Franklin Institute Dynamometer.

At the conclusion of the demonstration Prof. Marks, after alluding to the importance of the elements which he believed Mr. Tatham had succeeded in realizing in his construction, moved that a committee be appointed to subject the Dynamometer to a careful scientific investigation, and to report the results of such investigation to the Institute, with such recommendations as they might deem proper to make. The motion was carried, and Vice President Graff named the following members to constitute the committee, viz: Prof. W. D. Marks (ch'n), Coleman Sellers, Washington Jones, Hugo Bilgram, and C. Chabot.

The meeting was thereupon adjourned.

WILLIAM H. WAHL, *Secretary.*